Vol. I

TRANSCRIPT OF RECORD

Supreme Court of the United States

OCTOBER TERM, 1942

No. 369

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA, PETITIONER,

vs.

THE UNITED STATES

No. 373

THE UNITED STATES, PETITIONER

vs.

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA

ON WRITS OF CERTIORARI TO THE COURT OF CLAIMS

PETITIONS FOR CERTIORARI FILED { **SEPTEMBER 2, 1942.** **SEPTEMBER 3, 1942.**

CERTIORARI GRANTED DECEMBER 14, 1942.

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IN THE COURT OF CLAIMS OF THE UNITED STATES

No. 33642

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA

vs.

THE UNITED STATES

I. HISTORY OF PROCEEDINGS

The original petition was filed July 29, 1916, by Richard A. Ford, Esq., as Attorney of Record.

On May 21, 1919, supplemental petition was filed.

On June 15, 1922, the amended supplemental petition was filed, which is as follows:

II. AMENDED AND SUPPLEMENTAL PETITION—Filed June 15, 1922

To the Honorable Chief Justice and Associate Justices of the Court of Claims of the United States:

Now comes the Marconi Wireless Telegraph Company of America, a corporation duly incorporated under the laws of the State of New Jersey, and files this its amended and supplemental petition against the United States pursuant to the provisions of the Act of Congress of June 25, 1910, entitled "An Act to Provide Additional Protection for Owners of Patents of the United States, and for other purposes," and also pursuant to the said Act of June 25, 1910, as amended by the Act of Congress approved July 1, 1918, Making Appropriations for the Naval Service; and respectfully shows to the court as follows:

First: That on the twenty-fifth day of June, 1910, and for a long time prior thereto, your petitioner was the [fol. 4] owner by duly recorded assignments of the entire title to each of the following described Letters Patent of the United States, namely:

Re-Issue No. 11913 (Original No. 586193, July 13, 1897), granted to G. Marconi on June 4, 1901, for transmitting electrical impulses and signals and apparatus therefor;

No. 609154, granted to O. J. Lodge on August 16, 1898, for inventions in electric telegraphy;
No. 763772, granted to G. Marconi on June 28, 1904, for apparatus for wireless telegraphy;
No. 803864, granted to J. A. Fleming on November 7, 1905, for instrument for converting alternating electrical currents into continuous currents;

by each of which said Letters Patent of the United States there was granted and secured to the assignor of your petitioner, named therein, his heirs and assigns, for the term of seventeen (17) years from the date thereof, respectively, the full, sole and exclusive right and liberty of making, using and selling the invention set forth in and by said Letters Patent throughout the United States and the territories thereof to the full end of the term thereof, which said Letters Patent, or duly certified copies thereof, and duly certified copies of the assignment of each of said Letters Patent to it, your petitioner now here produces and shows to the court, and the same are prayed to be read as part hereof.

Second: Your petitioner alleges that it was, from the date of the assignments thereof to it as aforesaid and during all the period from the twenty-fifth day of June, 1910, to, to-wit, the twenty-first day of November, 1919, the sole and exclusive owner of the inventions set forth in said Letters Patent, and the sole and exclusive owner of said Letters Patent of the United States numbered Re-Issue 11913 (Original No. 586193), 609154, 763772 and [fol. 5] 803864; that it is the sole and exclusive owner of the claim herein made and set forth, and that no action on the claim herein made and set forth has been had either by the Congress of the United States or by any of the Departments of the Government.

Your petitioner further shows that it is an American corporation, controlled by loyal American citizens, and that in the conduct of its business it at all times bore true allegiance to the Government of the United States, and has not in any way aided, abetted or given encouragement to any of the enemies of the Government.

Third: That your petitioner is advised by its counsel and believes and therefore avers that said Letters Patent of the United States, numbered Re-Issue 11913 (Original

No. 586193), 609154, 763772 and 803864, as hereinabove set forth, are valid and effectual in law to secure to your petitioner the exclusive rights and privileges thereby granted, and that your petitioner was, during all the period covered by the claim herein made, entitled to the sole and exclusive use and enjoyment of the said inventions and the said Letters Patent, and to the exclusive rights and privileges thereby granted and to receive the profits of the same, except in so far as your petitioner may have granted to others the right to use the same.

That the infringement by the United States of the said Letters Patent, as herein complained of, has been in violation of the exclusive rights and privileges granted by said Letters Patent and has seriously interfered with the enjoyment thereof by your petitioner, as it was by law entitled to do, and has prevented it from receiving the profits to which it was entitled as the sole owner of said inventions and said Letters Patent.

Fourth: That none of the inventions covered and claimed in the said Letters Patent were discovered or invented by the patentees thereof while such patentee was an employee [fol. 6] of the Government of the United States, nor was any of such patentees in the employment or service of the Government of the United States at the time said Letters Patent were assigned to your petitioner.

Fifth: That your petitioner is informed and believes, and therefore avers, that the United States, through its officers and agents, and especially through the officers or officials of its Department of the Navy, its Department of War, its Department of Commerce, and various of the bureaus of its said Departments, and through other officers and agents the names of whom are to your petitioner unknown but information of which is in the possession of the Government, which is requested to produce the same, and otherwise, well knowing the premises and the exclusive rights and privileges granted by said Letters Patent as aforesaid, and that such exclusive rights and privileges had become vested by duly recorded assignments in your petitioner, and further well knowing that the validity of said Letters Patent had been adjudicated in favor of your petitioner by several of the courts of the United States, has, since the twenty-fifth day of June, 1910, and prior to the twenty-first day of November, 1919, without license of

your petitioner, and without lawful right, made, constructed or manufactured, or caused or procured to be made, constructed or manufactured, and used, or caused or procured to be used, a very large amount of apparatus containing and embodying in use the inventions covered and claimed in and by said Letters Patent of the United States, numbered Re-Issue 11913 (Original No. 586193), 609154, 763772 and 803864, in violation and infringement of said Letters Patent and of the rights of your petitioner thereunder. That in violation and infringement of said Letters Patent and of the exclusive rights and privileges of your petitioner thereunder, the United States, through its said officers and agents, has, since the said twenty-fifth [fol. 7] day of June, 1910, entered into agreements and placed orders with divers persons and corporations, among such persons and corporations being Emil J. Simon, Fritz Lowenstein, Telefunken Wireless Telegraph Company, Atlantic Communication Company, Kilbourne and Clark Company, Wireless Specialty Apparatus Company, International Radio Signalling Company, Western Electric Company, Westinghouse Electric Manufacturing Company, General Electric Company, Liberty Electric Company, American Radio and Research Corporation, General Radio Company, DeForest Radio Telegraph and Telephone Company, Wireless Improvement Company, United Wireless Telegraph Company, Cutting and Washington, Electric Ind. Manufacturing Company, Clapp Eastham Company, John Firth, Radio Telegraph and Telephone Company, Marine Engineering Company, Ira M. Henry, Bellini Tosi Company, Patent Exploitation Company, Federal Telegraph Company, Dubilier Condenser Company, Morehead Laboratory, National Electrical Supply Company, Lowenstein Radio Company, Garwood Manufacturing Company, Sperry Gyroscope Company, International Radio Telegraph Company, Adams Morgan Company, Liberty Electric Corporation, Manhattan Electric Supply Company, Conn. Telephone and Telegraph Company, L. S. Brach Supply Company, American Pulley Company, Holtzer Cabot Electric Company, Crocker Wheeler Company, American Propeller Company, The Robins & Myers Company, DeLaurier's Aircraft Company, Automatic Telegraph Manufacturing Company, Roy O. Fitch, Dyro Motor Company, American Gas Accum. Company, Electric Importing Company, Richard Pfund, Radio

Controller Corporation, Foote-Pierson Company, Doran Bros. Elec. Company, Roy E. Hall, Louis Cohen, Muirhead and Company, H. Krautz Manufacturing Company, Dore-[fol. 8] mus Machine Company, Electric Dental Company, Central Scientific Company, and other persons and corporations whose names are to your petitioner unknown but information of which is in the possession of the Government, which is requested to produce the same, for wireless apparatus which constituted an infringement of said Letters Patent and the inventions set forth thereby, and has used, or caused or procured to be used, the apparatus so obtained. That such unlawful and unauthorized making, construction, manufacture and use of your petitioner's said patented inventions, and such violation and infringement of your petitioner's said Letters Patent, has resulted in great injury, damage and loss to your petitioner, to-wit, as your petitioner is informed and believes, and therefore avers, in the aggregate sum of six million dollars ($6,000,000), which sum is justly due to your petitioner, no part thereof having been paid, and which sum, or such other reasonable compensation as this honorable court may find to be due to your petitioner, your petitioner avers it is justly entitled to recover, after allowing all just credits and offsets.

Sixth: Your petitioner further shows the court that it has at all times been ready, able and willing to furnish and supply to the United States any of the inventions set forth in said Letters Patent, together with apparatus embodying said inventions and to charge the United States only reasonable prices therefor.

Seventh: Your petitioner further shows the court that upon learning of the violation and infringement by the United States of the said Letters Patent and the inventions set forth and claimed therein of which inventions and Letters Patent your petitioner was, as before alleged, the sole and exclusive owner, your petitioner notified and warned the United States to desist therefrom, well believing that it would cease the same; but that, notwithstanding such [fol. 9] notice and warning, the United States neglected and refused so to do and continued to make, construct, manufacture and use, or cause or procure to be made, constructed, manufactured and used, the inventions set forth

and claimed in said Letters Patent, in violation and infringement of your petitioner's rights in the premises.

Eighth: Your petitioner's said claim for compensation for the use of said patented inventions is not based in any part on the use by the United States of any article or apparatus owned, leased or used by or in the possession of the United States prior to June 25, 1910.

Wherefore your petitioner prays judgment in its favor against the United States for the sum of six million dollars ($6,000,000), and for such other and further relief as to the court may seem just.

Marconi Wireless Telegraph Company of America,
By E. J. Nally, Vice-President. (Seal.)

Attest: L. MacConnach. Asst. Secretary.
Richard A. Ford, Attorney for Petitioner.

[fol. 10] *Duly sworn to by Edward J. Nally. Jurat omitted in printing.*

[fol. 11] III. General Traverse—Filed August 23, 1938 (out of time by leave of co rt)

And now comes the Attorney General, on behalf of the United States, and answering the amended and supplemental petition of claimant herein, denies each and every allegation therein contained; and asks judgment that the amended and supplemental petition be dismissed.

Paul Campbell, Acting Assistant Attorney General.
JFM.

IV. Argument and Submission of Case

On March 5, 1935, the case was argued and submitted on merits by Mr. Thomas G. Haight and Mr. Edward W. Vaill for plaintiff, and by Mr. Clifton V. Edwards and Mr. John F. Mothershead for defendant.

[fol. 12] V. **Special Findings of Fact, Conclusion of Law and Opinion of the Court by Green, J.**— Filed November 4, 1935

Messrs. Thomas G. Haight and *Edward W. Vail* for plaintiff. *Messrs. James R. Sheffield, James J. Cosgrove, Abel E. Blackmar, Jr., Richard A. Ford*, and *Sheffield & Betts* were on the briefs.

Messrs. Clifton V. Edwards and *J. F. Mothershead*, with whom was *Mr. Assistant Attorney General George C. Sweeney*, for defendant. *Mr. Paul P. Stoutenburgh* was on the briefs.

This case having been heard by the Court of Claims, the court, upon the evidence adduced, makes the following

Special Findings of Fact

I. Plaintiff was a corporation of New Jersey for more than six years preceding the filing of the original petition herein on July 29, 1916, and until November 20, 1919, when an agreement was entered into with the Radio Corporation of America and beyond which time no claim for infringement is apparently made on any of the patents in suit.

II. Guglielmo Marconi, an Italian subject, on December 7, 1896, applied for letters patent of the United States for improvements in transmitting electrical signals and patent #586193 dated July 13, 1897, was granted to him. On April 1, 1901, he applied for a reissue of said patent and the same was granted bearing reissue #11913 dated June 4, 1901, for transmitting electrical impulses and signals and apparatus therefor to Marconi's Wireless Telegraph Company, Limited, of England. On March 6, 1905, this patent, together with all claims for past infringement thereof, was assigned to plaintiff.

Exhibit 19, a copy of Reissue patent #11913, and exhibit 24, a stipulated copy of the assignment of the patent to plaintiff, are by reference made a part of this finding.

III. Oliver Joseph Lodge, a British subject, applied February 1, 1898, for letters patent of the United States for improvements in electric telegraphy and patent #609154 dated August 16, 1898, was granted him. He owned this

patent until he assigned it, together with the right to sue for past infringements, to the plaintiff on March 19, 1912. [fol. 13] Exhibit 20, a copy of the Lodge patent #609154, and exhibit 25, a stipulated copy of the assignment of said patent to plaintiff, are by reference made a part of this finding.

IV. The aforementioned Marconi also applied November 10, 1900, for letters patent of the United States #763772 dated June 28, 1904, which was granted to Marconi's Wireless Telegraph Company, Limited, of London, England. Said patent was assigned with the Reissue patent #11913 to plaintiff, together with all claims for past infringement thereof, on March 6, 1905.

Exhibit 21, a copy of the Marconi patent #763772, and exhibits 23 and 24, stipulated copies of assignments of said patent, are by reference made a part of this finding.

John Ambrose Fleming, a British subject, on April 19, 1905, applied for letters patent of the United States for improvements in "Instrument for converting alternating electric currents into continuous currents." The invention and application were assigned September 13, 1905, to plaintiff and the patent thereon, #803684 dated November 7, 1905, was issued to plaintiff.

Exhibit 22, a copy of the Fleming patent #803684, and exhibit 26, a stipulated copy of the assignment of said patent to plaintiff, are by reference made a part of this finding.

V. On November 26, 1919, plaintiff sold to the defendant for $1,450,000 forty-five coastal wireless stations and a large number of ship stations. The contract of sale contained, among other things, the following provision:

"The Marconi Company hereby stipulates and agrees that the compensation above named is intended to be and is accepted by it as compensation in full for and on account of any and everything transferred by it under this agreement, and that it will not make claim and that the Government is not bound to pay any other or further sum than the above-named consideration as payment, royalty, or other compensation *on account of its patent rights involved in any of the apparatus hereby transferred.*" (Italics ours.)

It is admitted that the apparatus so sold included the combinations of the Marconi reissue patent, the Lodge patent, and the Marconi patent #763772.

VI. On October 16, 1929, a stipulation was entered into between the parties, in which paragraphs 2 and 7 are as follows:

"2. That on November 20, 1919, the claimant entered into an agreement with the Radio Corporation of America, a copy of which is marked herein as defendant's exhibit C-7, and that said agreement has not been terminated or canceled, nor has it been modified except as stated below in carrying out some of the provisions thereof.

"7. That on August 2, 1920, the claimant caused to be filed in the office of the Secretary of State of New Jersey a certificate of dissolution of which a certified copy is offered in evidence by claimant and marked 'Claimant's Exhibit No. 359.' "

This stipulation and the copy of the certificate of dissolution, plaintiff's exhibit 359, are by reference made a part of this finding. The circular of the Radio Corporation of America and the Marconi Wireless Telegraph Company of America dated December 20, 1919, and the form of stockholders' agreement, both referred to in the quotation in paragraph 4 of the stipulation of October 16, 1929, are also [fol. 14] by reference made a part of this finding, being embodied in the stipulation of June 1, 1933.

VII. An agreement was entered into November 20, 1919, between Radio Corporation of America and plaintiff, which contained the following statements:

"Article I.

"1. It is desired that the Radio Corporation acquire all the assets of the Marconi Company, present and future, including its goodwill and business, rights of action, patent rights, and all other rights and property to which it is now or may hereafter become entitled, except the 'reserved assets' hereinafter described * * *. All claims and rights of action which the Marconi Company possesses being transferred by this present agreement to the Radio Corporation, it is understood and agreed that from such transfer there are reserved each and all of the claims or rights of action as follows, and that in any proceeding with respect thereto the Marconi Company may sue in its own name, joining the Radio Corporation as complainant if

necessary. The claims or rights of action enumerated below are the 'reserved assets' above referred to.

"(a) A claim against the United States Government arising from unlicensed use by and for the Government of the apparatus covered by the patents of the Marconi Company.

* * * * * * *

"Article II.

"6. The Marconi Company warrants and agrees to keep its organization alive until the Radio Corporation shall in writing agree that it may be dissolved and the Marconi Company may at any time require the Radio Corporation to pay the expenses incurred thereafter in carrying out the foregoing agreement to keep its organization alive provided that at the same time the stockholders of the Marconi Company assign to the Radio Corporation a majority of the voting shares of the Marconi Company. * * *

"7. The Marconi Company agrees to prosecute at its own expense all the claims which are the 'reserved assets' above described, and the Marconi Company agrees that all amounts received in cash by it at any time but after paying expenses for maintaining its corporate organization and the prosecution of such claims shall forthwith be paid to the Radio Corporation, and it is agreed that the Radio Corporation shall from time to time on such payments issue therefor preferred stock of a par amount equal to the amount of cash so paid subject to the provisions of sections 3, 4, and 8 of this article, provided that when and if such par amount of preferred stock so delivered shall amount to five million dollars ($5,000,000), if the Aldene factory is transferred under section 4 of this article, or four million five hundred thousand dollars ($4,500,000), if it is not transferred, *and in any case on December 31, 1930, regardless of the amount then issued, the Marconi Company shall forthwith assign to the Radio Corporation the reserved assets and all of them and all other assets which it then has without further compensation or consideration.* (Italics ours.)

"8. The Radio Corporation will advance such sums to the Marconi Company as may from time to time be reasonably necessary in the opinion of the counsel hereinafter [fol. 15] mentioned to prosecute the claims or rights of action mentioned above as well as for the defense of any patent suits now pending against the Marconi Company or

hereafter brought with reference to operations of the Marconi Company prior to the coming into effect hereof. * * * All amounts advanced, and all recoveries against the Marconi Company with respect to operations which it performed prior to the date hereof, shall be charged against and deducted from such reserved assets. * * *"

Said agreement, defendant's exhibit C-7, is by reference made a part of this finding.

On December 29, 1930, the Radio Corporation of America and the trustees in dissolution of the plaintiff entered into an agreement postponing the transfer of the reserved assets referred to in section 7 of article II of the agreement of November 20, 1919 (herein referred to in findings VI and VII), until there shall have been a final determination of the claims against the United States in the courts of last resort having jurisdiction over said claims, and until the said claims shall have been allowed, the amounts thereof ascertained and warrants issued for their payment.

A stipulation dated June 14, 1933, having attached thereto said agreement of December 29, 1930, is by reference made a part of this finding.

VIII. An undated assignment from plaintiff to Radio Corporation of America, stipulated to have been executed and delivered November 20, 1919, and recorded in the Patent Office December 30, 1919, in Liber R 109, page 78, conveyed—

"all inventions, licenses, and patent rights of any character whatsoever, owned by it * * * together with all claims for profits and damages by reason of past infringement * * * with the exception of the following claims or rights of action which are excepted from this assignment and are reserved to said Marconi Wireless Telegraph Company of America;

"(*a*) A claim against the United States Government arising from unlicensed use by and for the Government of the apparatus covered by the patents of the Marconi Company * * *."

This assignment expressly mentioned the two patents in suit then unexpired, namely, Marconi #763722 and Fleming #803684. It did not specifically mention the Marconi reissue #11913 and Lodge #609154.

Another assignment from plaintiff to Radio Corporation of America dated December 8, 1919, and recorded in the Patent Office December 30, 1919, in Liber R 109, page 86, confirmed the undated assignment recorded the same date.

A further assignment from plantiff to Radio Corporation of America dated December 8, 1919, and recorded in the Patent Office December 30, 1919, in Liber R 109, page 93, expressly mentioned the two expired patents in suit, Marconi reissue #11913 and Lodge #609154, and assigned these patents, together with all claims for profits and damages by reason of past infringement, except for the same reservation previously mentioned.

These three assignments, being exhibit 362, are by reference made a part of this finding.

[fol. 16] Marconi Reissue #11913

IX. The reissue patent #11913 relates to a—

"complete system or mechanism capable of artificially producing Hertz oscillations and forming the same into and propagating them as definite signals and capable of receiving and reproducing, telegraphically, such definite signals; * * *."

The embodiment shown by figs. 10 and 11 of the patent, reproduced below, is the basis of the alleged infringement.

Fig. 10.

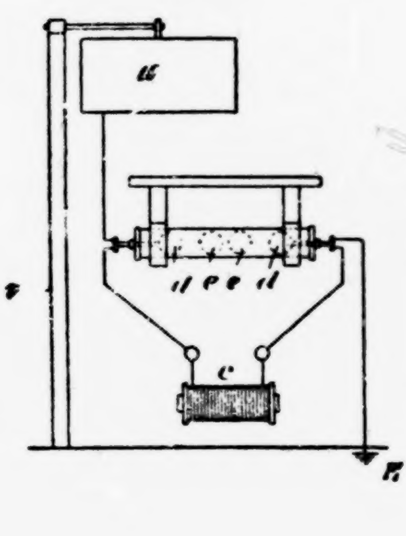
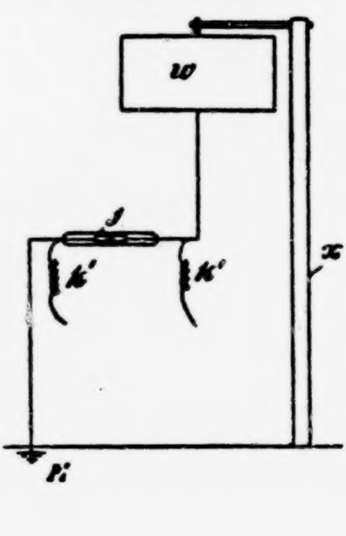


Fig. 11.



To one skilled in the art a transmitting station is shown at fig. 10, having a Morse key and battery in the primary circuit, not shown, of an induction or Ruhmkorff coil *c* or other source of high tension, high frequency current. A spark gap *d, e, e, d,* in the secondary circuit has one side grounded at *E* and the other side connected to an elevated wire and plate *u* insulated from the earth on the pole *v*.

The receiving station in fig. 11 has a coherer or imperfect electrical contact type detector *j* connected on one side to an elevated conductor *w* insulated from the earth, while the other side of the detector is grounded at *E*. Choke coils k^1k^1 are provided to keep high frequency waves out of the local battery circuit, not shown in fig. 11 but shown in fig. 4 of the patent. A relay in this local battery circuit operates a stronger battery circuit containing a sounder and a trembler for tapping the coherer so that its circuit will be broken after the incoming waves have ceased. Metal plates are provided of a size to cause the receiving system to resonate with the wave length transmitted.

X. The only claim in suit of the reissue patent reads as follows:

"3. The combination, in an apparatus for communicating electrical signals, of a spark producer at the transmitting station, an earth connection to one end of the spark producer, an insulated conductor connected to the other end, an imperfect electrical contact at the receiving sta-
[fol. 17] tion, an earth connection to one end of the contact, an insulated conductor connected to the other end, and a circuit through the contact, substantially as and for the purpose described."

The spark producer at the transmitting station, shown in fig. 10, includes coil *c* and its connected spark gap. The earth connection is shown in fig. 10 as being made on the right side of spark producer. The insulated conductor connected to the other end of the spark producer includes the elevated plate *u*. At the receiving station in fig. 11 the imperfect electrical contact *j* has the earth connection on the left side, an insulated conductor plate *w* on the right side, and a circuit through the contact as described. The insulated conductor at both the transmitting and receiving station is elevated to increase the range of signalling.

XI. More than two years after the date of the original patent, Marconi applied for his reissue, alleging his original

patent was believed defective because some of the claims were thought to cover apparatus employed by Prof. Popoff.

The original patent #586193 stated—

"The tube *j* may be replaced by other forms of imperfect electrical contacts, but this is not desirable."

In the reissue patent the meaning of this quotation was changed by omitting the words, "but this is not desirable." No satisfactory explanation of the reasons for this change in the scope of the description of the invention has been given.

The closest claim in the original patent to the claim now in suit was no. 43, which was the same as present claim 3 of the reissue patent except that it lacked the words "in an apparatus for communicating electrical signals," and also the phrase at the end of the claim, "substantially as and for the purpose described."

Certified copies of the file wrapper of the original and reissue patents, exhibits Z-5 and A-6, are by reference made a part of this finding.

XII. Plaintiff's apparatus was marked with name plates and some of these name plates lacked any marking as to the reissue patent in suit, although another and previously used name plate for the same type apparatus, i. e., switchboards and transmitting transformers, did contain a reference to the numb r or date of this reissue patent.

The United States was orally notified of its use of the Marconi inventions with particular reference to the four patents in suit in the winter or spring of 1912 by Mr. Griggs, president of plaintiff, and by Mr. Sheffield, counsel for and a director of plaintiff, at a White House conference at which the President and the Secretary of War, Secretary of the Navy, the Attorney General, and the Secretary of Commerce were among those present. The proofs do not satisfactorily show that any copy of any of the patents was shown at the conference, or that any particular apparatus was alleged to infringe or that any allegation was made that the United States would be held liable for any alleged infringement. Title to the Lodge patent in suit was not acquired by plaintiff until March 19, 1912. Written notice of the two Marconi patents and of the Lodge patent in suit and of their alleged infringement was given by registered mail to the Navy Department and to the War Department on March 7, 1913, and on March 8, 1913, respectively.

[fol. 18] Previous to the winter or spring of 1912 the Navy Departm ' had been notified of an adjudication of the two Marcon. patents in suit but not of their alleged infringement.

XIII. A British Marconi patent # 12039 was filed June 2, 1896, and corresponds to the reissue patent # 11913 in suit. Claims 15 and 16 of this British patent read as follows:

"15. A receiver consisting of a sensitive tube or other imperfect contact inserted in a circuit, one end of the sensitive tube or other imperfect contact being put to earth whilst the other end is connected to an insulated conductor.

"16. The combination of a transmitter having one end of its sparking appliance or poles connected to earth, and the other to an insulated conductor, with a receiver as is mentioned in claim 15."

The earliest date to which plaintiff is entitled for constructive reduction to practice of the invention of the reissue patent is December 7, 1896, the filing date in this country. The provisions of the International Convention had not then become law.

The term of this British patent was for fourteen years from the filing of the provisional specification of June 2, 1896.

The British patent # 12309 of 1896 had its complete specification accepted July 2, 1897, before the issue of the original patent # 586193 in this country July 13, 1897. This British patent was published July 31, 1897, and sealed September 21, 1897.

Section 15 of the British patents act of 1883 was in force until January 1, 1908, and states:

"After the acceptance of a complete specification and until the date of sealing a patent in respect thereof, or the expiration of the time for sealing, applicant shall have the like privileges and rights as if a patent for the invention had been sealed on the date of the acceptance of the complete specification: Provided that an applicant shall not be entitled to institute any proceeding for infringement, unless and until the patent for the invention has been granted to him."

A copy of this British patent, exhibit 339, is by reference made a part of this finding.

XIV. The subject matter of the reissue patent went into wide use until displaced by later improvements. This reissue patent has been called the plain antenna patent.

XV. The alleged infringement of the Marconi reissue patent is for unlicensed use by the United States of transmitting and receiving sets between July 29, 1910, and July 13, 1914.

The receiving sets, the use of which has been satisfactorily proven in connection with this alleged infringement, are all of the type using a crystal detector. As a detector the crystal functions in a different manner from the coherer or imperfect electrical contact of the patent in suit, in that the crystal acts substantially as a rectifier or one-way valve allowing much larger portions of the waves to flow in one direction than in the other and thereby enabling speech or music to be heard. The use of the crystal as a detector was not discovered until after this Marconi patent.

XVI. Tests were made with the aid of improvements developed after the invention in suit for the purpose of demonstrating that with critical adjustments the coherer [fol. 19] might be made to transmit speech and music. These tests did not demonstrate the presence of any new properties or functions inherent in the coherer when used in the manner intended by the patent. The patent contemplated such a degree of imperfection in the contact of the particles in the coherer that the local battery circuit would be broken on tapping, but plaintiff in conducting these tests tried to keep the circuit through these particles from being broken and to this extent operated a coherer in a different manner from that contemplated by the patent. Later improvements used for this test included a transformer and tuning means connected in shunt with the detector to provide more sensitive reception than was possible with the plain antenna connections of the patent.

XVII. The words "imperfect electrical contact", as found in claim 15 of the Marconi patent, are used in their ordinary meaning and would be well understood by those skilled in the art if not also by those having little technical knowledge. Lodge described six classes of detectors for Hertzian waves more than two years before the filing date of the original patent of Marconi in a journal called the "London Electrician", June 15 and 22, 1894, pp. 187-190, and 204-205, and also discussed the utility of imperfect contact devices as detectors. One skilled in the art would understand that the

imperfect contact devices disclosed by Lodge did not include the other types or classes of then known detectors not making use of an imperfect electrical contact in reacting to Hertzian waves. In the same way those skilled in the art would understand the reference in the Marconi patent to "an imperfect electrical contact" to restrict the claim to apparatus making use of some form of an imperfect contact inserted in a circuit.

Exhibit E-4, the Lodge article in "London Electrician" of 1894, is by reference made a part of this finding.

XVIII. The crystal detector does not utilize an imperfect electrical contact in the detection of Hertzian waves but requires a good small contact of such degree of perfection that it is frequently necessary, when the contact becomes imperfect, to abandon the imperfect and unsuitable contact area and find a new sensitive spot or good contact. Occasionally the crystal is cleaned with alcohol.

The possession of substantial electrical resistance by a detector does not necessarily denote a bad contact device. Variation in resistance is not synonymous with an imperfect electrical contact.

The use of an imperfect electrical contact detector by the United States has not been satisfactorily proven. No use of the crystal detector in a manner contemplated for the imperfect electrical contact of the Marconi reissue patent, has been satisfactorily proven. Imperfect electrical contact detectors were largely superseded by more sensitive detectors before July 29, 1910.

XIX. The ticker detector construction has not been satisfactorily proven in sufficient detail to permit any finding as to whether or not such is an imperfect electrical contact type detector. No date of use prior to July 13, 1914, has been satisfactorily proven for the ticker detector.

XX. The transmitting circuits and receiving circuits of the wireless telegraph sets used by defendant and alleged [fol. 20] to infringe claim 3 of the Marconi reissue patent, all include a transformer connection between the antenna circuit and a closed circuit which latter circuit in the transmitter includes the spark producer or gap and in the receiver includes the crystal detector.

The transformers are of two types: (a) separate primary and secondary windings; (b) an auto-transformer type of winding.

In all instances in which a transformer having separate primary and secondary windings is utilized, no electrical connection is existent between the ground and the antenna and the spark producer or gap in the transmitter, or between the ground and the antenna and the detector in the receiver.

With this type of transformer no physical metallic connection exists; the coupling is purely inductive in character.

Such arrangement of transmitting and receiving circuits is shown in a diagram of the apparatus of the Wireless Specialty Apparatus Company, illustrated in Finding XXII.

XXI. In the transmitting and receiving circuits utilizing the autotransformer type of coupling, a single inductance coil is utilized and certain turns of this inductance are in common with both the antenna circuit and the associated closed circuit in which is included either the spark producer or the detector.

The fact that the use of the autotransformer establishes a direct electrical communication between the primary and secondary windings in the coupling of the closed circuit to the open circuit, is merely incidental to the construction of the autotransformer, the true function of which is to electromagnetically couple the open and closed circuits together, and such electrical connection is not for the purpose of connecting the receiving antenna and the ground directly to the detector so as to pass all of the high-frequency currents generated in the antenna through the detector, as was the case in the Marconi patent.

On the contrary, with respect to the transmitting circuit, such connection is merely incidental and not for the purpose of connecting the antenna and the earth directly to the spark producer or gap.

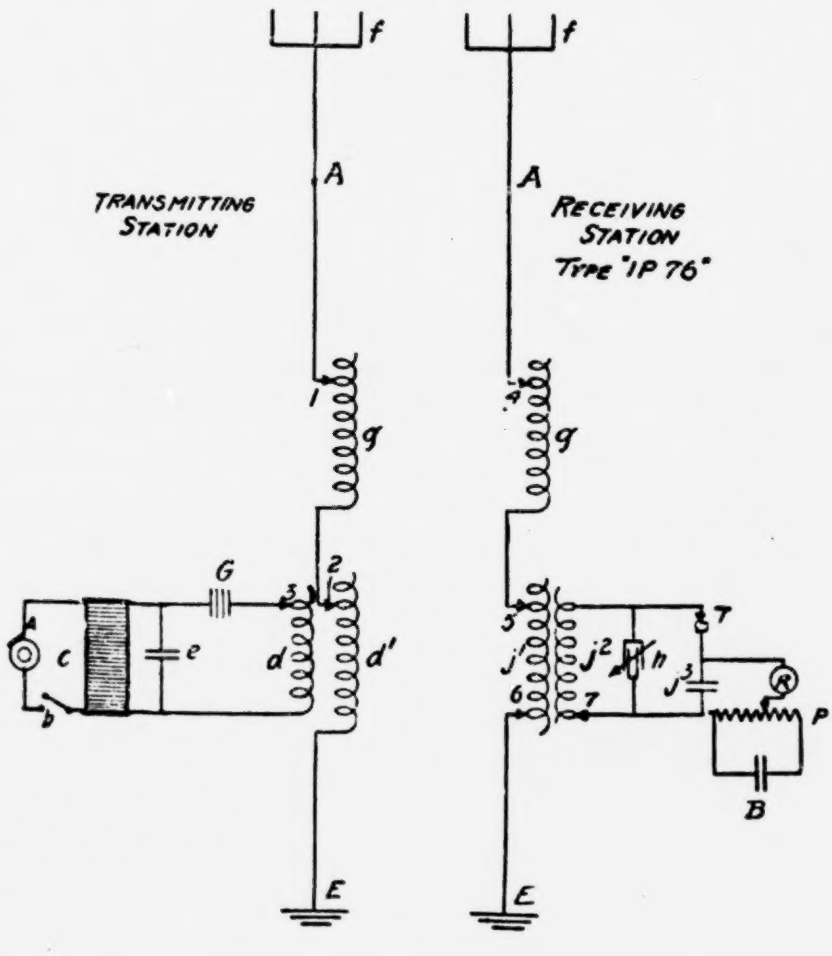
In the Marconi reissue patent the spark gap and detector, which were relatively high resistant devices, were located between the elevated conductor and the ground connection in the antenna circuit, and the location of these devices in a separate closed circuit coupled electromagnetically with the antenna circuit lessened the resistance in the antenna circuit and permitted much sharper tuning and selectivity. In the defendant's device the spark gap and detector are not in the antenna at all, they are in closed circuits only associated inductively and through oscillation transformers with the grounded antenna in the manner indicated in Finding XX.

The Telefunken sets, plaintiff's exhibit 79, utilized an autotransformer coupling in the transmitting system and a transformer having separate primary and secondary windings in the receiving system.

The National Electric Supply Company's field pack set, plaintiff's exhibit 80, utilized transformers having separate primary and secondary windings in both the transmitting and receiving systems.

[fol. 21] The Foote-Pierson pack set, plaintiff's exhibit 102, utilized autotransformer coupling in both the transmitting and receiving systems.

XXII. The diagram below illustrates the apparatus constructed by the Wireless Specialty Apparatus Company.



XXIII. The prior art relied on by defendant to show lack of novelty and invention and to limit the scope of the claim of the patent includes the following United States patents:

Smith, # 247127, September 13, 1881;
Phelps, # 312506, February 17, 1885;
Dolbear, # 350299, October 5, 1886;
Edison, # 465971, December 29, 1891;

and the following publications:

An article by Lodge in "London Electrician" June 8, 1894, pp. 153-155; June 15, 1894, pp. 186-190; June 22, 1894, pp. 204-205; July 6, 1894, pp. 271-274; July 13, 1894, p. 299; July 20, 1894, pp. 332-335.

[fol. 22] Article by DeTunzelmann in "London Electrician", September 14, 1888, pp. 587-589; September 21, 1888, pp. 625-627; September 28, 1888, pp. 663-665; October 5, 1888, pp. 697, 698; October 12, 1888, pp. 725-726; October 19, 1888, pp. 757-758; October 26, 1888, pp. 788-789; November 9, 1888, pp. 16-18; November 16, 1888, pp. 41-44.

"Inventions, Researches and Writings of Nikola Tesla", by Martin, pp. 165, 169, 174, 188-193, 202, 203, 207, 208, 210-213, 225, 226, 231, 234, 303-313, 317, 332, 333, 337, 340-349, 384, 488, 489.

Article by Crookes in "Fortnightly Review", February 1892, pp. 173-181.

Article by Popoff in the Journal of the Russian Physico Chemical Society, St. Petersburg, 1896.

"The Alternate Current Transformer", by Fleming, London, 1893, p. 419.

"Electric Waves", by Hertz, London, 1893, pp. 183-184.

Journal of the Society of Arts, February 23, 1894, pp. 274-280, "Electric Signaling without Wires", by Preece.

The foregoing patents and publications, exhibits L-4, M-4, N-4, O-4, E-4, F-2, B-4, A-4, F-4, K-4, J-4, and S-6, are by reference made a part of this finding.

XXIV. The Smith patent #247127 relates to the inductive transmission of telephone signals between the metal roof of a moving car and a stationary wire strung along

the tracks as close to the car roof as possible. No spark-producer is contemplated or used, and the transmission without wires was through a small space as close as possible to the top of the cars. The medium for signaling was not intended to be by Hertzian waves.

The Phelps patent #312506 is for another inductive telegraphic transmission system for cars. There is no spark-producer for the generation of Hertzian oscillations. The apparatus on the car, shown at X in fig. 4, is not grounded.

Dolbear's patent #350299 is for the telephonic communication by what was said to be currents flowing through the earth when the grounded wires at the transmitting station A and receiving station B were said to be at different potentials. There was no spark-producer at the transmitting station. Dolbear had no idea of using Hertzian waves or oscillations.

Edison's patent #465971, December 29, 1891, discloses a system for telegraphing without wires by induction. A Morse key short-circuited a rapid make and break device in the primary circuit of an induction coil. The secondary circuit of such coil was grounded on one side and connected at the other to an elevated conducting surface through "an electro-motograph telephone receiver." There was no spark-producer for the generation of Hertz oscillations.

XXV. The Lodge article in the "London Electrician" of June and July 1894, reviewed the knowledge of the art of Hertzian oscillations but did not disclose the combination of apparatus called for by reissue claim 3. A number of different types of detectors of Hertzian oscillations, including coherers, were discussed and some of Hertz's experiments were repeated.

The DeTunzelmann article in the "London Electrician" of 1888, was an earlier discussion of the Hertz experiments. [fol. 23] Wave lengths or frequencies are discussed, but no disclosure is made of any combination of apparatus as set forth in claim 3 of the reissue patent.

The Martin book on Tesla's work relates to transmission by induction, to resonance, to peculiar lighting effects, and to the production of arcs in various ways. There is no disclosure of an imperfect electrical contact receiver nor

any definite idea for the transmission and reception of signals by Hertzian waves. This article states:

"I think that beyond doubt it is possible to operate electrical devices in a city through the ground or pipe system by resonance from an electrical oscillator located at a central point. But the practical solution of this problem would be of incomparably smaller benefit to man than the realization of the scheme of transmitting intelligence, or perhaps power, to any distance through the earth or environing medium. If this is at all possible, distance does not mean anything. Proper apparatus must first be produced by means of which the problem can be attacked, and I have devoted much thought to this subject. I am firmly convinced that it can be done, and hope that we shall live to see it done."

The article further shows that Tesla used a powerful alternating current.

The Crookes article in the "Fortnightly Review" of 1892, referred to the work of Hertz and Lodge with ether waves and prophesied the transmission of Morse code signals by having the sending and receiving apparatus tuned to a special wave length, but described no apparatus capable of carrying such a prophecy into effect, much less did this publication reveal the particular apparatus of the claim in suit.

The Popoff article did disclose a coherer grounded on one side and connected on the other side to an elevated insulated conductor for indicating thunderstorms. It failed to disclose a transmitting apparatus connected as called for by the claim in suit. This article stated—

"In conclusion I can express the hope that my apparatus, with further improvements of the same, may be adapted to the transmission of signals at a distance by the aid of quick electric vibrations, as soon as the source of such vibrations, possessing sufficient energy, will be found."

The other publications likewise do not disclose the apparatus of the claim in suit.

XXVI. No prior patent or publication discloses the combination of the claim in suit.

The invention of the Marconi reissue patent made possible new results by permitting the use of the Morse code

for signalling with Hertz waves, and permitted signalling with Hertz waves to greater distances than was previously possible.

Lodge Patent #609154

XXVII. With alternating currents of given frequency a circuit will carry its strongest current under a given pressure or voltage when there is a condition of resonance, or, in other words, when the natural period of the circuit corresponds with the frequency of the current. In the alternating current circuit its natural period depends on the value of its capacity and inductance, also called self-inductance. A helical coil of wire has principally inductance and an [fol. 24] electric condenser has essentially capacity. Variation in the value of either the inductance or capacity changes the period of the circuit.

The Lodge patent relates to the provision of a self-inductance coil between a pair of capacity areas in an oscillating circuit of either or both a sending or receiving set for Hertzian wave telegraphy. Such a coil may be adjustable to vary the value of its self-inductance. The purpose of such coil is to attain a condition of resonance or syntony in the oscillating circuit whereby the oscillations will be prolonged and a feeble impulse is gradually strengthened by cumulative action until it causes a perceptible effect on the principle of sympathetic resonance.

In the figures of the patent drawings on pages 14 and 15, fig. 1 was said to show the art prior to Lodge without the use of any inductance coil in either the transmitting or receiving circuits. Fig. 2 is one illustration of an oscillating circuit embodying the invention and having the inductance coil h^4 in series with the spark gap h^2h^3 and the condenser plates or capacity areas h and h^1. Wires h^8 lead to the source of high-frequency oscillations. One of the capacity areas may be the earth.

Fig. 3 is similar to fig. 2 except that the gap h^2h^3 is optionally short-circuited by the bridge h^9 and the wires h^8 from the high-frequency source are connected through gaps h^6 and h^7 instead of directly connected so that the circuit through the capacity area and coil h^4 may oscillate independently of the supply circuit h^8. The detector circuit x includes a coherer e, battery f, and sounder g, all connected across the coil h^4. The bridge h^9 must short-circuit the gap

h^2h^3 for the reception of messages when the transmitter is not in operation.

Fig. 4 is an arrangement like unto fig. 3 except that coil h^4 is in two parts, one on each side of the gap h^2h^3. Leyden jar capacitors j are placed in the supply circuit and an inductance k acts as a bypass but does not prevent the formation of sparks at the gaps.

Figs. 5, 6, 7, and 8 illustrate different shapes for one or both the capacity areas.

The coil is adapted for adjustment in value of its inductance by cutting in or out some or many of the turns in figs. 9 and 10.

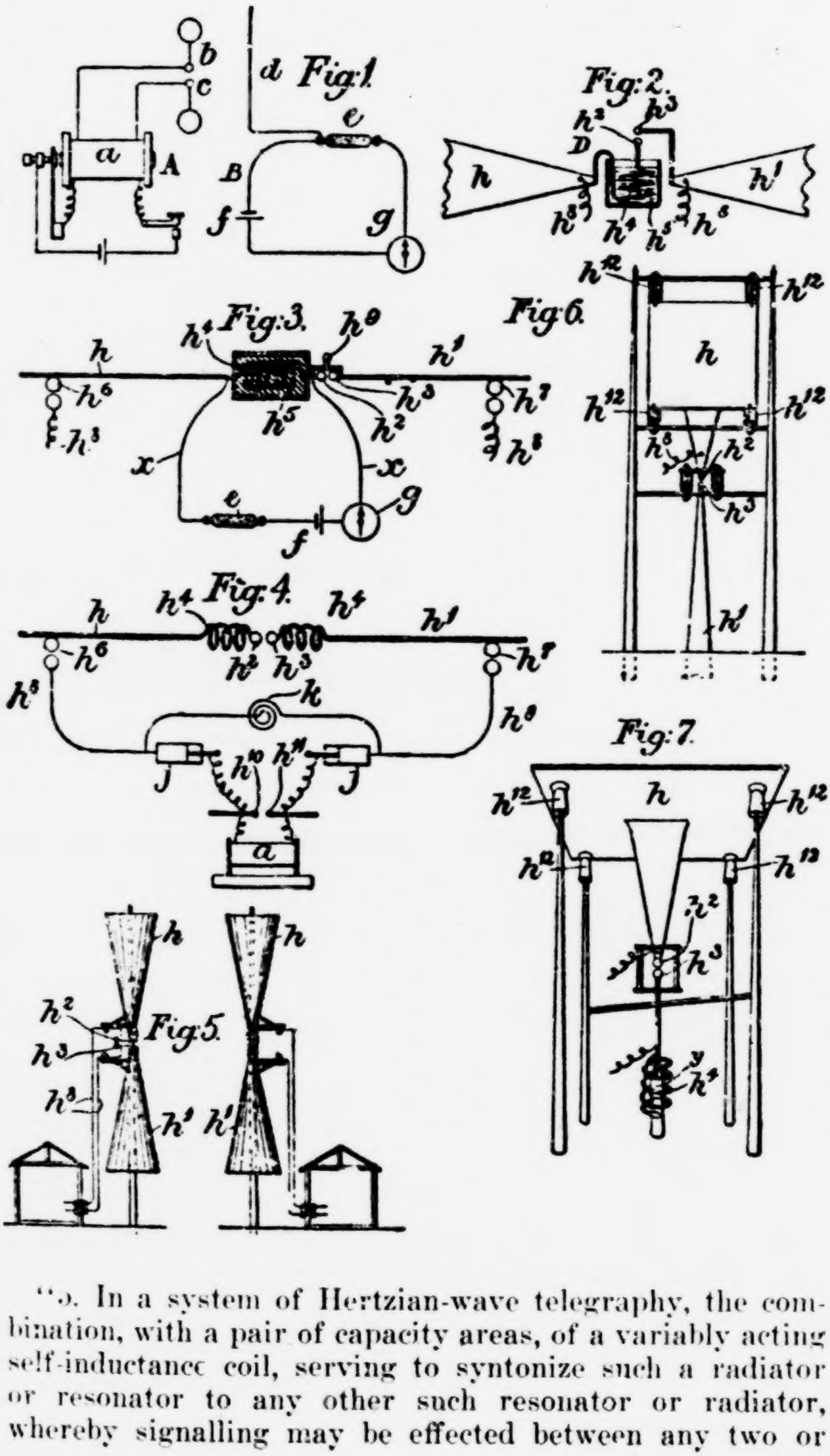
The receiver of fig. 12 is similar to that of fig. 2 with the addition of a resistance or capacity w placed in shunt with the sounder q. In fig. 13 the detector circuit is connected with the oscillating circuit through a transformer u in order to leave the oscillating circuit free to vibrate without disturbance from the attached wires.

Lodge contemplated varying either the inductance or capacity to attain syntony or resonance.

XXVIII. The claims in suit are numbers 1, 2, and 5 of the Lodge patent, which read as follows:

"1. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, of a self-inductance coil inserted between them electrically for the purpose of prolonging any electrical oscillations excited in the system and constituting such a system a radiator of definite frequency or pitch.

"2. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, of a self-inductance coil inserted between them electrically for the purpose [fol. 25] of prolonging any electrical oscillations excited in the system, thus constituting the system a resonator or absorber of definite frequency or pitch, and a distant radiator of corresponding period capable of acting cumulatively.



"5. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, of a variably acting self-inductance coil, serving to syntonize such a radiator or resonator to any other such resonator or radiator, whereby signalling may be effected between any two or

[fol. 26] more correspondingly attuned stations without disturbing other differently attuned stations."

XXIX. The pair of capacity areas in fig. 2 includes metal plates h and h^1, and one of these capacity areas may be the earth. The self-inductance coil h^4 is inserted between the capacity areas for the purpose of prolonging any electrical oscillations excited in the system and constituting such a system a radiator of definite frequency or pitch. In other words, the value of the inductance coil between the capacity areas gives the circuit a definite effective period or pitch. Claim 1 is specific to a transmitter or apparatus in which the oscillating circuit constitutes a radiator.

Fig: 8.

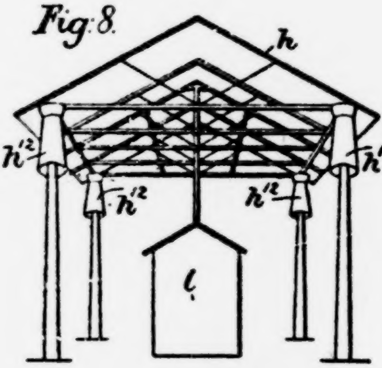


Fig: 9.

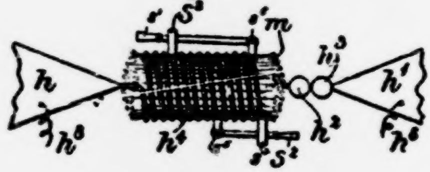


Fig: 12.

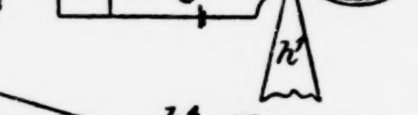


Fig: 10.

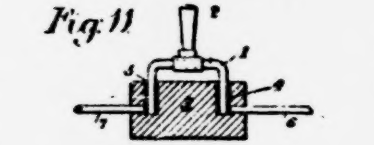
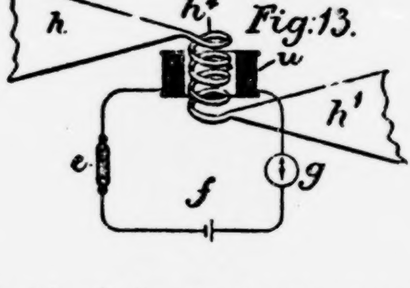


Fig: 11.

Fig: 13.



The combination in claim 2 is similar to that in claim 1, except that the system constitutes an absorber or receiving

station of definite frequency and also calls for a distant radiator or sending station of corresponding period.

The combination in claim 5 is more specific by the inclusion of a variably acting self-inductance coil or, in other words, a coil that is adjustable to vary its self-inductance, in a transmitter or receiver in order that the transmitter may be tuned with another station without disturbing operation of substantially differently tuned stations.

[fol. 27] XXX. The earliest date for constructive reduction to practice available to Lodge is February 1, 1898, the filing date in this country. The provisions of the International Convention were not law when this patent was filed and granted.

XXXI. During prosecution in the Patent Office the examiner cited against claim 1 of the Lodge application—

"Marconi # 586193 taken in connection with the well-known state of the art of syntonizing electrical circuits as disclosed, for example, in each of the following references:

"Hutin, et al. # 522564 July 3, 1894.

"Wiedmann's 'Annalen', published in Leipsic, 1891, vol. 44, page 74, * * *.

"The Marconi patent shows it to be old to syntonize a radiator by suitably varying its capacity. The other references show that it is old to syntonize circuits employing either Hertzian waves or other forms of electrical waves by suitably proportioning self-induction to the capacity of the circuits. It does not amount to invention, therefore, to substitute for the means used by Marconi for syntonizing his circuits, another old and well-known method of accomplishing this result as shown by each of the other references. This claim is further rejected upon the disclosure contained in the above-cited article by Bjerknes in Wiedmann's 'Annalen' when taken alone. This reference shows it to be old to transmit Her[t]zian waves by a suitable radiator consisting of capacity areas and a self-induction coil inserted therebetween."

Claims 2 and 5 were also rejected upon references, and reasons cited against claim 1. It reply, Lodge said:

"Marconi does not effectively syntonize at all. He may think he does, but capacity alone will not syntonize. * * * I add self-induction to capacity * * * to prolong the

oscillations * * * and for the first time to render effective syntony possible * * *. Hutin's specification * * * will not work. * * * I know the Bjerknes paper in Wiedmann's 'Annalen', vol. 44. It does not disclose a method of syntonizing electric vibrators."

Subsequently these claims were allowed.

A copy of the file wrapper of the Lodge patent, exhibit 32, is by reference made a part of this finding.

XXXII. The Lodge invention went into wide and almost universal use. It increased the range for signaling with Hertz waves, and increased selectivity.

XXXIII. It was not the universal practice of plaintiff to mark all name plates, and especially its earlier ones, with notice of the Lodge patent because title to this patent was not acquired until 1912.

Actual notice of the Lodge patent and its infringement by the United States was given as stated in finding XII.

XXXIV. The Wireless Specialty Apparatus Company diagram on page 10 has in the transmitting station for Hertzian-wave telegraphy a pair of capacity areas comprising the capacity area of the antenna f and another capacity area constituted by the ground E. A self-inductance coil, which is adjustable to vary its inductance, is located between these areas and such coil in the transmitter is made up of the variable parts g and d^1, the latter of which is the secondary of the transformer d d^1 This coil enables the oscillating circuit $f\ Agd^1E$ to be a radiator of definite frequency or pitch in [fol. 28] which the oscillations excited in the system are prolonged over what they would be if such inductances were absent. The receiving station has a two-part variable inductance coil gj^1 in the oscillating circuit $fAgj^1E$ constituting the system an absorber of definite frequency or pitch adapted to cooperate with the distant sending station or radiator of corresponding period capable of acting cumulatively. Both the transmitter and receiver have their inductances adjustable whereby signalling may be effected between any two or more correspondingly attuned stations without disturbing other differently attuned stations. This Wireless Specialty Apparatus Company layout embodies the invention of claims 1, 2, and 5 of the Lodge patent in suit

and was used by the United States before the expiration of the patent on August 16, 1915. Other apparatus used by the United States and embodying the invention of these claims includes at least that made by the Foote-Pierson Company, National Electric Supply Company, Telefunken Wireless Tel. Company, Kilbourne & Clark Mfg. Company, and United States Navy type.

XXXV. The prior art publications relied on to show anticipation and lack of invention include:

Transactions of the American Therapeutic Association, November 1894;

An article entitled "D'Arsonval's Modification of Currents of Great Frequency";

Lightning Conductors and Lightning Guards, London, 1892, by Lodge, pp. 351-355;

Popoff article in the Electrician, London, December 10, 897, p. 253;

London Electrician, October 22, 1897, p. 869;

DeTunzelmann article in London Electrician, September 14 to November 16, 1888;

An article by Crookes in Fortnightly Review, 1892, pp. 173-181;

Article by Lodge in London Electrician, June 8 to July 20, 1894;

Pages from the Martin book on Tesla;

London Electrician, pages from June 8 to July 20, 1894.

Copies of these publications, exhibits F-2, G-2, H-2, I-2, A-4, B-4, C-4, E-4, and I-4, are by reference made a part of this finding.

XXXVI. The Popoff article shows an inductance in shunt with the coherer connected on one side to the ground and on the other side to a lightning rod which necessarily possessed capacity to the earth, but such inductance was functionally no more like this invention than was the inductance of the relay in the local battery circuit of Marconi's original patent #586193, and neither was adapted to tune the oscillating circuit as intended by Lodge.

Marconi in his patent #586193 (the original Marconi patent which was reissued as the first patent in suit) contemplated making the plates *k* of such length that the

receiver would be "electrically tuned with the electric oscillations transmitted", but as pointed out by Lodge in his file wrapper argument before the Patent Office, such tuning means would not satisfactorily accomplish its purpose. Marconi in his patent #586193 apparently did not appreciate the desirability of tuning the primary oscillating circuit by the use of an inductance coil, and did not contemplate varying the effective tuning of the receiver to one of several transmitters.

[fol. 29] The American Therapeutic Association publication told how to determine and vary the period of an oscillating circuit by modifying the inductance and capacity.

The patents to Pupin #640516 dated January 2, 1900 filed May 28, 1895; Hutin et al., #838545 dated December 18, 1906, filed May 9, 1894; and Stone #577214, February 16, 1897, filed September 10, 1896, show that the laws of closed resonant circuits in general were known prior to the Lodge invention, but such patents do not show knowledge of the desirability of tuning an open oscillating circuit for Hertzian-wave signalling.

No one prior to Lodge appreciated the desirability of tuning the oscillating circuits of both the transmitter and receiver for the purpose intended and in the manner performed by him.

The laws regarding the relationship of capacity and inductance to achieve the tuning of an alternating current circuit were known prior to Lodge's invention. There has been no satisfactory evidence submitted to show that the elevated wire of a Hertzian-wave transmitter or receiver and the ground connection were known to constitute an electric condenser in the open oscillating circuit prior to the Lodge invention. Lodge appears to have been the first to recognize that the elevated wire and ground connection constituted a condenser and was apparently the first to realize the desirability of applying the known laws of resonance for closed circuits to a Marconi open oscillating circuit.

Exhibits U-2, S-2, and T-3 are by reference made a part of this finding.

XXXVII. The British patent to Oliver Joseph Lodge #11575 was filed May 10, 1897, over seven months before the United States application for the same invention, the patent in suit #609154, was filed. This British applica-

tion was referred to in the oath of and corresponds to the United States application for the patent #609154. This British patent was sealed October 25, 1898, and its complete specification accepted August 10, 1898, and was obtained by the inventor of the United States patent in suit.

A copy of this British patent to Lodge #11575 of May 10, 1897, is embodied in the stipulation of June 1, 1933, and such stipulation is by reference made a part of this finding.

Marconi #763772

XXXVIII. This invention relates to means for providing a stronger transmitted signal in wireless telegraphy and to means for rendering the receiver more selective than had theretofore been the practice. Specifically, the invention comprises a variably tuned antenna circuit inductively coupled through an oscillation transformer to a tuned closed oscillating circuit containing a spark gap. This is best illustrated by figs. 1 and 2 of the patent reproduced on page 19.

In fig. 1 *a* is a battery or other source of current for the primary winding of an induction coil *c*, the circuit closing key *b* being for the purpose of making the dots and dashes of the Morse code. The secondary of the induction coil *c* includes a spark gap as a generator of high frequency oscillations located in a closed circuit containing the winding *d* of an oscillation transformer and a variable condenser *e*. The secondary d^1 of the transformer is in the [fol. 30] antenna circuit and is grounded on one side at *E* and connected on the other side to a variable inductance coil *g* and an elevated plate *f* through the vertical wire *A*.

In fig. 2 a receiving station is illustrated and comprises a tuned antenna circuit $f^1Ag^1j^1E$, g^1 being a variable inductance and j^1 the primary of a transformer connected to the earth at *E*. In shunt with the primary winding j^1 is a variable condenser *h*. The secondary j^2 of the transformer is in two parts, each of which is connected to a variable inductance coil g^2 and to the condenser j^3. A detector *T* is connected between the variable inductance coils g^2, and a condenser h^1 is sometimes connected in shunt with the detector. A battery *B* and relay *R* controlling a telegraph instrumer are placed in shunt with the condenser j^3. Choke coils c^1c^2 prevent the high frequency oscillations getting into the battery and relay.

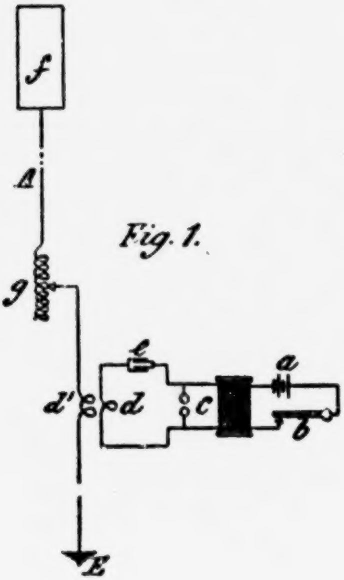


Fig. 1.

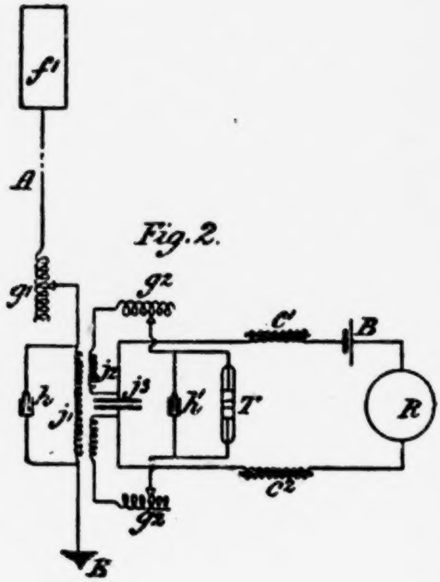


Fig. 2.

Marconi intended each of the transformer circuits at the transmitting and receiving stations to be tuned to the same frequency or time periods or octaves of each other. This was in order to get the most persistent or strongest signals radiated and the most sensitive reception at the receiver. By adjusting the receiving circuits to a detuned condition, the receiver becomes nonresponsive to the transmitted signals.

XXXIX. Marconi specifically describes the construction of the primary and secondary of his oscillation transformers. The best results and sharpest tuning with his apparatus would be present when there was loose coupling between the transformer windings. Tightening the coupling makes the tuning broader and less sharp and does not make either the transmitter or receiver as effective as it would be with loose coupling. This is because with tight coupling neither transformer winding has the same resonant condition that it does when loose or alone.

[fol. 31] XL. The claims in suit may be divided in three classes, the transmitter claims 1, 3, 6, 8, 11, and 12, and receiver claims 2, 13, 14, 16, 17, 18, and 19, and the combined transmitter and receiver claims 10 and 20. These claims read as follows:

"1. At a station employed in a wireless-telegraph system, a signaling instrument comprising an induction coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency; an open circuit electrically connected with the oscillation producer aforesaid and a variable inductance included in the open circuit, substantially as and for the purpose described.

"2. At a station employed in a wireless-telegraph system, an oscillation-receiving conductor, a variable inductance connected with said conductor; a wave-responsive device electrically connected with said conductor and in circuit with a condenser, substantially as and for the purpose described.

"3. At a station employed in a wireless-telegraph system, a signaling instrument comprising an induction coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency, and the primary circuit of which includes a generator; means for varying the primary circuit; an open circuit electrically connected with the oscillation producer aforesaid, and a variable inductance included in the open circuit, substantially as and for the purpose described.

"6. At a transmitting station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to a condenser circuit discharging through a means which automatically causes oscillations of the desired frequency, and means for adjusting the oscillation period of each of the two circuits connected with the transformer to bring them into accord with each other, substantially as described.

"8. At a transmitting station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, a variable inductance being included in said circuit, and whose primary is connected to a condenser circuit dis-

charging through a means which automatically causes oscillations of the desired frequency, substantially as described.

"10. A system of wireless telegraphy, in which the transmitting station and the receiving station each contains an oscillation transformer, one circuit of which is an open circuit and the other a closed circuit, the two circuits at each station being in electrical resonance with each other and in electrical resonance with the circuits at the other station, substantially as described.

"11. In apparatus for communicating electrical signals, the combination, with an oscillation transformer, at a transmitting station, of an induction coil; an electric circuit containing the secondary of said coil, a condenser and the primary coil of the oscillation transformer; a producer of electric waves of high frequency electrically connected with the secondary of the induction coil; a signaling instrument in circuit with the primary of the induction coil; the secondary coil of the oscillation transformer; electrically connected, [fol. 32] at one end to capacity and, at the other end, to an inductance, and an aerial conductor connected to the inductance, substantially as and for the purpose described.

"12. In apparatus for communicating electrical signals, the combination, with an oscillation transformer, at a transmitting station, of an induction coil; an electric circuit containing the secondary of the said coil, a condenser and the primary coil of the oscillation transformer; a producer of electric waves of high frequency connected with the secondary of the induction coil; a signaling instrument in circuit with the primary of the induction coil; the secondary coil of the oscillation transformer electrically connected, at one end, to capacity and, at the other end, to a variable inductance, and an aerial conductor connected to the variable inductance, substantially as and for the purpose described.

"13. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a variable inductance being included in said circuit, a wave-responsive device electrically connected with the other winding of the oscillation

transformer, and a condenser in circuit with the wave-responsive device, substantially as described.

"14. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation transformer, and means for adjusting the two transformer circuits in electrical resonance with each other, substantially as described.

"16. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, an adjustable condenser in a shunt connected with the open circuit and around said transformer coil, a wave-responsive device electrically connected with the other coil of the oscillation transformer, and means for adjusting the two transformer circuits in electrical resonance with each other, substantially as described.

"17. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation transformer, and means included in each of said transformer circuits, for adjusting said circuits in electrical resonance with each other, substantially as described.

"18. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end, and capacity at the other end, a variable inductance being included in said open circuit, a wave-responsive device electrically connected with the other winding of the oscillation transformer, and a variable inductance included in cir-

cuit with the wave-responsive device, substantially as described.

[fol. 33] "19. In a system of wireless telegraphy, the combination at a receiving station, of an oscillation transformer; an open circuit comprising, in part, an aerial conductor connected with one end of the primary coil of the oscillation transformer; a connection from the other end of said coil to capacity; a variable inductance in said open circuit; and electrical connections from the secondary coil of the oscillation transformer to a receiving instrument, battery, condenser, wave-responsive device and a variable inductance, substantially as and for the purpose described.

"20. In a system of wireless telegraphy, a transmitting station containing an oscillation transformer, the primary of which is connected to a condenser circuit discharging through a spark gap which automatically causes electric waves of the desired frequency, the secondary of said transformer connected to an open circuit including a radiating conductor, and with a capacity and a coil for charging the condenser aforesaid; a receiving station containing an oscillation transformer, the primary of which is connected with an oscillation-receiving conductor and with a capacity, a wave-responsive device connected with the secondary of said transformer, and a receiving instrument connected with the wave-responsive device, all in combination with means for bringing the four transformer circuits, two at each station, into electrical resonance with each other, substantially as described."

Referring to claim 1, in fig. 1 there is shown a station employed in a wireless-telegraph system and a signaling instrument *abc* which comprises an induction coil *c*, the secondary of which includes a condenser formed by the spark gap. This gap discharges through a variable condenser means *e* which with the inductance *d* automatically causes oscillations of the desired frequency. The open antenna circuit $fAgd^1E$ is electrically connected with the spark-gap oscillation producer and contains a variable inductance *g* in this open circuit substantially as and for the purpose described. Claim 6 calls for a capacity connected at one end of the open radiating circuit and thus refers to the earth connection as a capacity, which might more properly be designated as a capacity area, as was done in

the Lodge patent in suit, since the earth constitutes one plate of a condenser instead of a capacity or condenser itself. Thus the same remarks concerning a capacity connected at one end of the open radiating circuit apply to claims 8 and 11 to 20, inclusive. Claim 6 includes the variable inductance g and the variable capacity e, each of which constitutes means for adjusting the oscillation period of its circuit to bring the two circuits into accord with each other. Claims 8 and 12 are limited to a variable inductance in the antenna circuit, while claim 11 calls for an inductance in addition to the transformer winding in the antenna circuit.

Referring to claim 2, fig. 2, the wave-responsive device or detector T is electrically connected with the antenna through the transformer j^1j^2 and the detector T is in circuit with a condenser j^3. There is a variable inductance g^1 in the open circuit.

XLI. The earliest date proven for this invention is November 10, 1900, the filing date in this country for constructive reduction to practice. The provisions of the International Convention were not in force when the Marconi patent #763772 was filed.

XLII. During prosecution in the Patent Office the examiner cited the following art against the Marconi application:

[fol. 34] British patent to Lodge #29505, of 1897;
Marconi #586193;
Pupin #640515;
A work of Hertz, by Lodge, pp. 7-8, The Electrician Co., London, 1894;
British patent to Marconi #7777, of 1900, corresponding to this application;
British patent to Thompson #22020, of 1899;
British patent to Braun #5104, of 1899;
British patent to Braun #1862, of 1899;
British patent to Braun #1863, of 1899;
British patent to Brown #14449, of 1899;
British patent to Wilson, et al. #10153, of 1899;
Lodge #609154;
Marconi #627650;
Marconi #647007;
Marconi #647008;

Marconi #647009;
Marconi #668315;
Tesla #649621;
Tesla #645576;
Ascoli in L'Elettricista, Rome, August 1897;
Slaby in Electrician, London, April 25 and May 2, 1902;
Fessenden, Proceedings of American Institute of Electrical Engineers, December 1899;
Fessenden #706735;
Fessenden #706736;
Stone #714756;
Stone #714831;
L'Industrie Electrique, Paris, June 25, 1898, p. 363;
L'Electrician, Paris, October 8, 1898, pp. 235-237;
Books by Ducretat, October 1898;
Book by Graffigny;
Book by Breton.

Exhibits 34, 119, X-2, Z-2, P-3, Q-3, B-6, C-6, D-6, E-6, F-6, and L-6 are by reference made a part of this finding.

XLIII. During the prosecution in the Patent Office of the Marconi application which materialized into the patent in suit, #763772, the examiner of the Patent Office, on June 3, 1902, rejected all claims but fifteen on Tesla, #649621, stating as follows with respect to this rejection:

"All the other claims are rejected on Tesla, 649621, May 15, 1900, division of 645576, Mch. 20, 1900, filed Sep. 2, 1897. On page 3, lines 113 to 125, the details of device G are given. This is an electrical oscillator comprising an alternating current generator charging a condenser and an interrupter, which is a spark gap, for discharging the same. The primary of a transformer is fed by this oscillation producing circuit. The secondary is connected to the ground at one end and to an elevated conductor at the other. The periods of the primary and secondary circuits are in accord with each other.

"Claims 4, 13, 14, and 16, which specify a variable inductance and means for adjusting the inductance, are not patentable over Tesla because Lodge, of record, has shown that it is old to adjust the period of a circuit by a variable [fol. 35] inductance; and claims 3 and 5, which specify an adjustable condenser, are not patentable over Tesla because applicant has shown in his prior patent No. 627650 that

this adjustment may be produced by a variable condenser. Since it is impossible to exactly calculate the values of the electromagnetic constants of two circuits for the purpose of making their time periods agree, it is fair to assume that the electrical oscillator of Tesla must necessarily be made with an adjustable inductance or condenser, or both."

Nearly two years later the case was resubmitted to a new examiner who on March 31, 1904, stated:

"The claims are all allowed except claims 4, 5, 6, and 7, which are rejected on the patent to Stone, #714756, December 2, 1902, application filed February 8, 1900.

"Stone shows in fig. 5 a transformer *M* whose secondary I_2 is connected to an open circuit including a radiating conductor *V* at one end and a capacity *E* at the other and whose primary I_1 is connected to a condenser circuit discharging through a spark gap, viz, the circuit CsI_1L. These circuits are in 'electrical resonance with each other', see lines 16-20, page 2. It is not stated how the elevated conductor is given a natural period equal to that of the oscillations impressed upon it but it is well known by all skilled in this art that this may be accomplished by adjusting the length of the elevated conductor, thereby adjusting the distributed capacity and the distributed inductance of the same until the natural period of such conductor is equal to the natural period of the condenser circuit CsI_1L. When this is done 'the frequency impressed upon the elevated conductor' is 'the same as the natural period or fundamental of such conductor', to quote from the Stone patent.

"Applicant discloses another means whereby the same result may be effected, viz, by including a 'variable inductance' in the elevated conductor. All claims which include this element are considered allowable over the Stone patent.

"In regard to claim 7 it may be said that Stone states that the operator at each station may at will adjust his apparatus in such a way as to place himself in communication with any other station (page 4, lines 28-36) and that he also states that this result may be effected by making the coil *L* of the condenser circuit adjustable (page 6, lines 76-81). Inasmuch as the period of an oscillating circuit depends upon the capacity of the condenser in the same way that it depends upon the inductance of the coil, it is held that it is not patentable to make the condenser *e* of applicant's oscillat-

ing circuit adjustable for the same purpose as Stone makes the coil *L* of his oscillating circuit adjustable.

"Claims 4, 5, 6, and 7 will be allowed if amended by inserting the words *a variable inductance and* after the word 'including' in line 3 of each claim."

The fig. 5 which is referred to in the statement of the examiner set out above is shown in the diagram illustrating the Stone patent which appears in finding LIII.

In response to this action by the examiner, Marconi canceled claims 4, 5, and 7 then in his application and substituted others in place thereof and amended claim 6 to specify that the "means for adjusting the oscillation period of the two circuits connected with the transformer" was for each of these two circuits. In the remarks in the last amendment of June 1, 1904, Marconi said:

[fol. 36] "The claims now presented all include an elevated conductor, or a circuit which is a good radiator of electric waves or oscillations, and means for adjusting the tune of such elevated conductor or radiating circuit. It is believed that the examiner recognizes the fact that the Stone patent does not show such an arrangement, and an early allowance is requested."

Exhibit X-5, a certified copy of the file wrapper of Marconi patent #763772, is by reference made a part of this finding.

XLIV. The invention of patent #763772 went into wide use in the United States and elsewhere. Apparatus embodying the invention of #763772 was employed in the first transatlantic radio signalling.

XLV. Some but not all name plates carried by apparatus manufactured by plaintiff were marked with notice of the Marconi patent #763772. The name plate of exhibit 14 was not so marked.

Defendant was notified of the alleged infringement of patent #763772, as stated in finding XII.

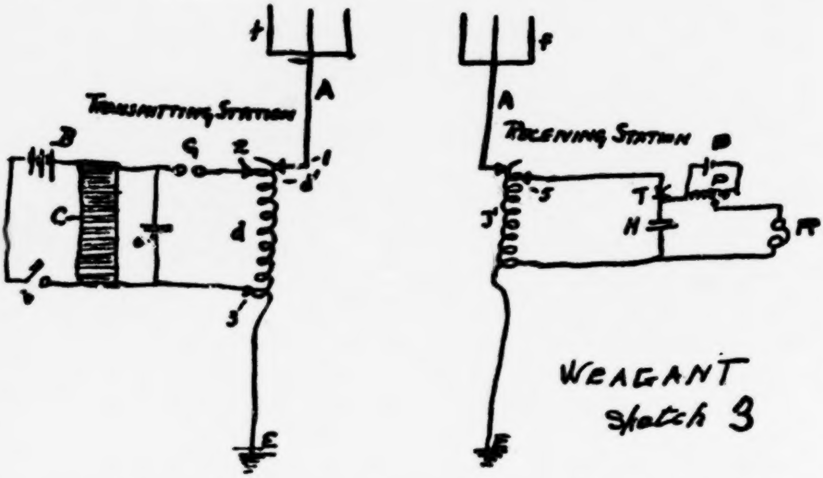
XLVI. The alleged infringing transmitting apparatus may be divided into three groups:

(*a*) The plain open gap apparatus;

(*b*) That having a rotary gap; and

(*c*) The larger group using a quenched gap.

A plain open gap apparatus used by the United States between 1910 and 1919 was made by the Foote-Pierson Company and is shown by exhibit 251, reproduced here:



An autotransformer having only one winding is electromagnetically the equivalent of a transformer having two separate windings. This apparatus has an induction coil *C*, the secondary circuit of which includes a condenser *G* discharging through a capacity e^1, and an inductance *d* which automatically cause oscillations of the desired frequency. An open circuit Ad^1E is electrically connected with the oscillation producer *G*. The secondary of the transformer constitutes a variable inductance d^1 included in the open circuit. This variable inductance is not in addition to the transformer winding or other electrical connection between the oscillation producer and the open circuit. The primary oscillating circuit Gde^1 may be varied or tuned at least to some extent by adjustment of the inductance *d* by [fol. 37] varying the position of the taps 2 and 3. In a similar manner the open circuit may be tuned, at least to some extent, by adjustment of its transformer tap. Coupled circuits are tuned at least to some extent when the currents flowing herein are greater than they would be with less tuning. There is no means in addition to the transformer for adjusting the oscillation period of each of the two circuits. The secondary circuit of the transmitter is connected to an open circuit including a radiating conductor *fA* at one end and a capacity area *E* at the other end.

The receiver of this Foote-Pierson pack, subject of exhibit 251, comprises an oscillation-receiving conductor *fA*

and a variable inductance constituted by the primary of the autotransformer connected with said conductor and with a capacity area E. There is a wave-responsive device T electrically connected with said conductor and in circuit with a condenser H. Here again the variable inductance of both transformer primary and secondary circuits is a part of, and not in addition to, the transformer. There is no condenser in the open circuit other than that formed by the antenna and the earth. At least some tuning of both the open and closed oscillating circuits to each other and to the period of the transmitter is possible.

All of the alleged infringing transmitters of the open-gap type possess an oscillation transformer, one circuit of which is a closed circuit containing a condenser and a spark producer in the form of a plain open gap. The other circuit of the oscillation transformer was connected to an open antenna radiating circuit; both of said circuits have inductance and capacity and are electromagnetically coupled and are capable of adjustment so that the two circuits, i. e., the open and the closed circuit, are in tune or electrical resonance with each other.

XLVII. The Marconi specification states, on page 2, as follows:

"My experiments have demonstrated that the best results are obtained at the transmitting station when I use a persistent oscillator, an electrical circuit of such a character that, if electromotive force is suddenly applied to it and the current then cut off, electrical oscillations are set up in the circuit which persist or are maintained for a long time, in the primary circuit, and use a good radiator, i. e., an electrical circuit which very quickly imparts the energy of electrical oscillations to the surrounding ether in the form of waves, in the secondary circuit."

The specification does not make it definite whether the "electrical circuit of such a character" as described above, relates to the functioning of the closed circuit when contemplated by itself or in combination with an open circuit. The persistence of the oscillations in a closed circuit is largely dependent upon the type of spark gap utilized therein.

The Marconi patent, on page 1, lines 82 to 88, indicates that the inventor does not limit himself to any specific type of spark producer or oscillation producer.

The claims in suit of Marconi patent #763772 in no way limit the patent monopoly expressed in them to any specific spark producer or to a closed circuit possessing elements which would cause it to function as a persistent oscillator when coupled to the open circuit.

XLVIII. The quenched spark gap is a spark producer made up of a series of metal disks separated by insulated washers. It functions to permit all of the energy of the closed oscillating circuit to be transferred to the open cir- [fol. 38] cuit in a comparatively few oscillations after which the spark is quenched and activity in the closed circuit having ceased, the open circuit continues to oscillate at its own frequency.

Defendant instructed its personnel in manuals distributed both by the United States Navy and the Signal Corps of the United States Army, that the closed transmitting circuit should be tuned in resonance with the open circuit in transmitting apparatus using the quenched gap. A Signal Corps pamphlet of 1916, plaintiff's exhibit 92, page 110, states that, "Tuning of the closed and open circuits to resonance and the determination of the correct coupling between them are the two most important adjustments in a quenched spark transmitter."

The oscillation transformers and their associated open and closed circuits utilized in connection with the quenched spark gap, are substantially similar in form and function to those utilized in connection with the plain open gap apparatus with the exception that a closer coupling can be achieved between the open and closed circuits.

Because the quenched gap was more efficient than the plain open gap, it began widely displacing the plain open gap about 1910, although some plain open-gap apparatus was retained and some was ordered and used during the war.

An example of a quenched-gap transmitter used by the United States between 1910 and 1919 is illustrated in exhibit 87, reproduced on page 10. The transmitter of exhibit 87 comprises an induction coil *c*, the secondary of which includes a condenser *G* discharging through a means comprising a condenser *e* and inductance *d* which automatically cause oscillations of the desired frequency. There is also an open circuit *fAgd*' *E* electrically connected with the oscillation producer and a variable inductance *gd*' included in the open circuit. The inductance in the open and closed

oscillating circuits constitutes a means for adjusting the oscillation period of each of the two circuits to bring them into at least substantial accord with each other. There are other makes of quenched-gap transmitters to which these remarks apply and which were used by the United States between 1910 and 1919.

The quenched-gap transmitters purchased by the United States and equipped with wave changers and wave- selecting switches are of the same general type, so far as this Marconi patent is concerned, as the apparatus of exhibit 87.

The wave-changing switches constituted a quick and convenient means for varying tuning conditions of the oscillating circuits. Such switches were used with both the quenched-gap and rotary-gap apparatus.

The receiver of exhibit 87 shown on page 10 was adapted to be used with a transmitter of any ype. The receiver illustrated in exhibit 87 comprised an oscillation-receiving conductor *fA* and a variable inductance gj^1 connected with said conductor. There was a wave-responsive device *T* electrically connected with said conductor and in circuit with a condenser j^3h. In this apparatus the variable inductance *g* is in addition to the transformer in both the transmitter and receiver. There is no condenser across the primary j^1 of the receiving transformer. Other similar makes of receiving apparatus were used by the United States between 1910 and 1919.

Some of the receiving sets used by the United States between 1910 and 1919 did have such a condenser in shunt with [fol. 39] the primary of the transformer as is shown, for example, by the Kilbourne & Clark receiver of exhibit 95 and by the Telefunken receiver of exhibit 79.

Exhibits 79 and 95 are by reference made a part of this finding.

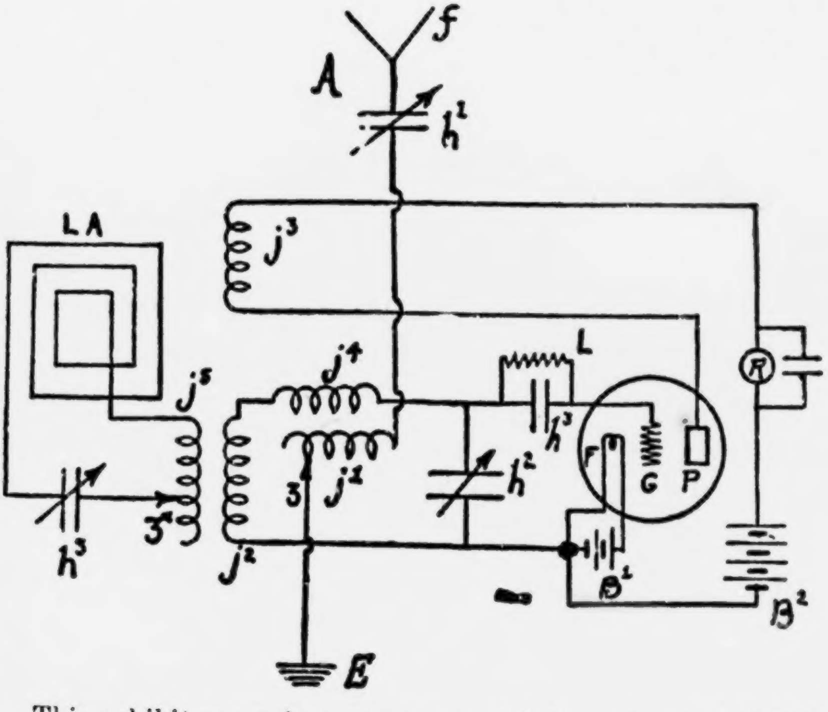
XLIX. A rotary spark gap of either the synchronous or non-synchronous type differ from the fixed or plain spark gap in that a plurality of spark electrodes are located on the periphery of a disk in such manner that when the disk is rotated they alternately approach and recede from a fixed spark electrode. Such functioning of the spark gap possesses the dual effect of cooling the spark electrode and effecting a lengthening of the spark and its quenching as the moving electrodes recede from the fixed electrode.

Such operation causes the primary circuit oscillations to tend to cease and the operation, therefore, approximates that of the quenched gap. The circuits and apparatus util-

ized by the rotary gap apparatus in the Government installation, with the exception of the spark producer or gap, are identical with those used with the plain gap, and the same condition of resonance between the open and closed circuits exists.

L. A direction finder used by the United States between 1910 and 1919 is shown by exhibit 115, here reproduced:

Direction Finder



This exhibit comprises an open oscillating circuit fAh^1j^1E containing a variable inductance j^1 constituted by the transformer primary winding, but such is not in addition to such [fol. 40] transformer winding. The open circuit was electrically connected with a wave-responsive device (a 3-electrode tube) in circuit with a condenser. There was no condenser across the primary of the oscillation transformer.

LI. The art relied on to show anticipation and lack of invention includes:

Marconi #586193 (original to reissue patent in suit);
Lodge #609154 (patent in suit);

Marconi #627650, dated June 27, 1899, filed January 5, 1899;

Marconi #647007, April 10, 1900, filed June 13, 1899;

Marconi #647008, April 10, 1900, filed June 13, 1899;

Marconi #647009, April 10, 1900, filed June 13, 1899;

British patent to Braun, #1862, of 1899;

British patent to Braun, #12420, of 1899;

Stone #577214, February 16, 1897;

Stone #638152;

Stone #714756, December 2, 1902, filed February 8, 1900;

Stone #714831, December 2, 1902, filed February 8, 1900;

The letters from Stone to Baker of June 30, 1899, and July 18, 1899;

Tesla #645576, March 20, 1900, filed September 2, 1897;

Pupin #519347, May 8, 1894;

Pupin #640516, January 2, 1900;

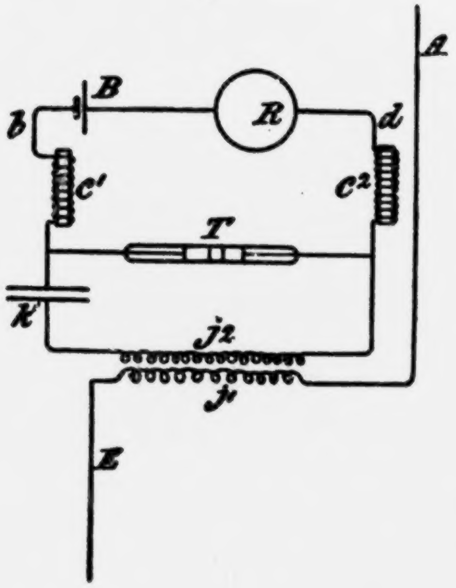
Tesla #649621, May 15, 1900, filed February 19, 1900;

British patent to Tesla #20981, of 1896.

Exhibits T-2, U-2, X-2, Y-2, Z-2, A-3, E-3, F-3, G-3, P-3, Q-3, T-3, U-3, B-6, C-6, D-6, E-6, L-6 are by reference made a part of this finding.

LII. Marconi #627650, fig. 1 of which is here reproduced, shows a receiver comprising an open circuit Aj^1E inductively coupled through an induction coil or transformer to the closed oscillating circuit j^2k^1 T in which is located the

Fig. 1.



[fol. 41] condenser k^1 and the coherer or wave-responsive device T. This patent states in lines 31-34 of page 1:

"It is desirable that the induction coil should be in tune or syntony with the electrical oscillation transmitted."

It was not known to Marconi at the time this patent was filed that it was desirable to have the closed oscillating circuit in tune with the open oscillating circuit. The statement quoted meant, to one skilled in the art at the time this patent was filed, that the primary or open circuit should be in tune with the transmitter according to the teaching of Lodge in his patent in suit. No means was shown for tuning the open circuit of this Marconi patent and it was not necessary to show any such means since the art after the Lodge patent in suit knew how to adjust a variable inductance coil in the open circuit to obtain the tuning desired, as well as by older and more tedious tuning operation of adjusting the length of the vertical wire. Such a variable inductance in the primary or open circuit would be implied by one skilled in the art at that time. After the disclosure of this patent #627650 it required no invention to have an oscillation-receiving conductor A connected to a variable inductance with a wave-responsive device T electrically connected with said conductor through the transformer $j^1 j^2$, and with a condenser k^1 in circuit with the detector.

Claim 2 of Marconi #763772 not being limited to the primary and secondary circuits being in tune, is directed to an arrangement contemplated by Marconi's earlier patent #627650.

Lines 38–42 of page 1 of patent #627650 state:

"The capacity of the condenser on the connection between the imperfect contact and the secondary of the coil should be varied (in order to obtain the best effects) if the length of the wave is varied." Do to the rather high resistance of the coherer T no sharp tuning would be possible on adjusting the capacity k^1. However, no satisfactory evidence has been submitted to show how else the "best effects" referred to could be obtained other than as the result of some tuning.

These quotations are not sufficiently clear to one skilled in the art at that time to point out the desirability of tuning both circuits to the same period.

LIII. The Stone patent #714756 was filed February 8, 1900, about two and a half months before the British patent to Marconi, #7777, of 1900, was filed.

Fig. 5.

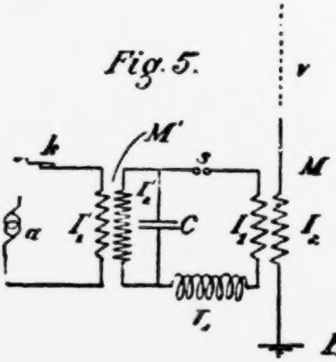


Fig. 6.

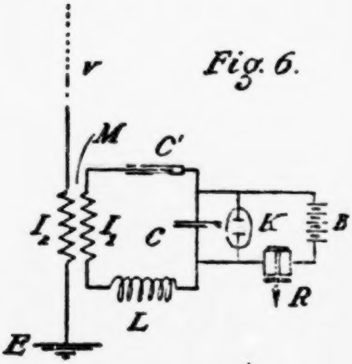


Fig. 7.

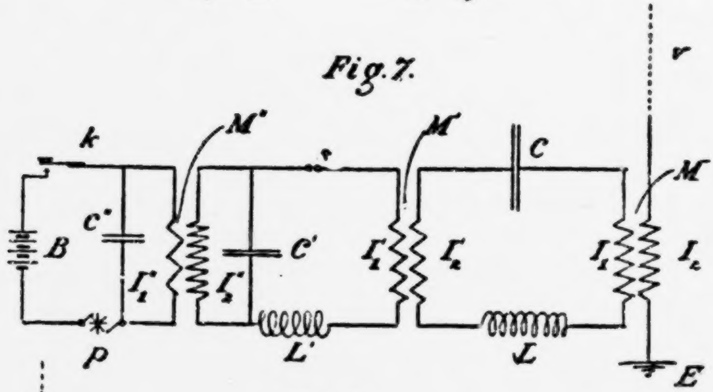
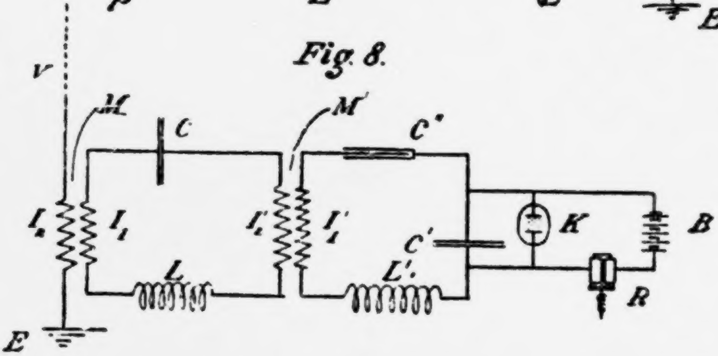


Fig. 8.



In fig. 5, reproduced on page 31 of this finding, is shown a transmitter having a telegraph key k in the primary of an induction coil M^1. In the secondary of this induction coil is a spark gap s which generates high-frequency oscillations through the closed circuit $sCLI_1$. This circuit is electrically connected through an oscillation transformer M with an open or antenna oscillating circuit v I_2E. The receiver is shown by fig. 6 to comprise an open oscillating circuit v I_2E inductively coupled through the transformer M with a closed oscillating circuit I_1C^1CL. A coherer or wave-responsive device K is connected across the condenser C. Figs. 7 and 8 are similar to figs 5 and 6 except that another closed oscillating circuit is placed between the open circuit

and the closed oscillating circuits of figs. 5 and 6 for the purpose of screening out other than the desired frequencies [fol. 42] to get sharper tuning. In figs. 13–15, reproduced on page 32 of this finding, are shown other embodiments of Stone's invention using more than one closed circuit coupled to one open circuit.

Stone was "a man possessed of unusual theoretical knowledge relative to the behavior of circuits, understanding fully the means necessary to tune an electrical circuit." Lines 16-29 of page 2 of the Stone patent state:

"Thus the frequency impressed upon the elevated conductor may or may not be the same as the natural period or fundamental of said conductor."

To one skilled in the art this meant the period or frequency of the closed circuit oscillations may or may not be the same as the natural period of the open circuit. When it is the same both circuits are in tune.

[fol. 43] Another pertinent portion of the Stone patent specification is found in lines 62-66 of page 6 which read as follows:

"The vertical wire may with advantage be so constructed as to be highly resonant to a particular frequency, and the harmonic vibrations impressed thereon may with advantage be of that frequency."

Fig. 13.

Fig. 14.

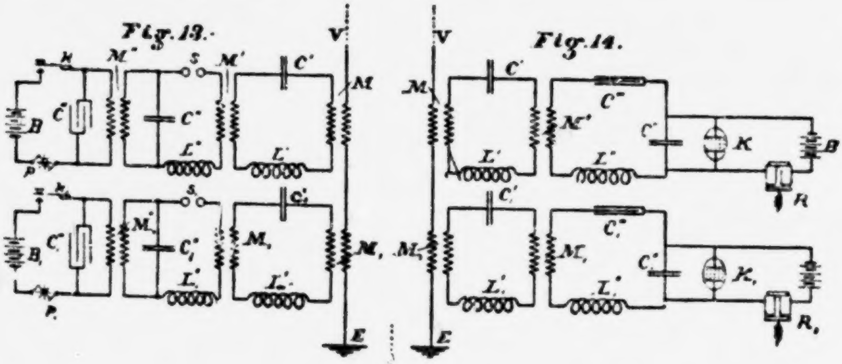
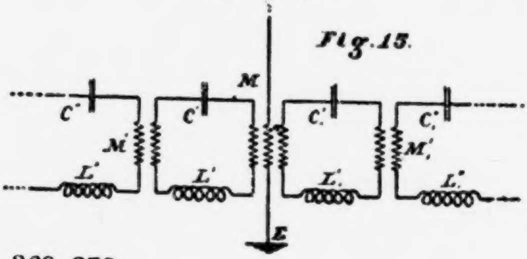


Fig. 15.



To one skilled in the art this meant that certain advantages were known to exist in having the open circuit of figs. 5 and 6 of the patent, for example, highly resonant or exactly in tune with the oscillations impressed upon it. On page 4 of the Stone patent specification lines 17-36 and 47-56 read as follows:

"When the apparatus at a particular station is attuned to the same periodicity as that of the electromagnetic waves emanating from a particular transmitting station, then this receiving station will respond to and be capable of selectively receiving messages from that particular transmitting station to the exclusion of messages simultaneously or otherwise sent from other transmitting stations in the neighborhood which generate electromagnetic waves of different periodicities. Moreover, by my invention the operator at the transmitting or receiving station may, at will, adjust the apparatus at his command in such a way as to place himself in communication with any one of a number of stations in the neighborhood by bringing his apparatus into resonance with the periodicity employed by the station with which intercommunication is desired.

• • • • • • •

"In order that the electric translating apparatus at the receiving station shall be operated only by electric waves of a single frequency and by no others, I interpose between the vertical conductor at the receiving station and the translating devices a resonant circuit or circuits attuned to the particular frequency of the electro-magnetic waves which [fol. 44] it is desired to have operate the translating devices."

Stone used circuit connections at his receiver to correspond with those at the transmitter, and his receiver and transmitter each had an open circuit inductively coupled to a closed circuit which was tuned to the frequency of the transmitted signal. From the suggestion to tune the open transmitter circuit it was obvious to one skilled in the art that the receiver open circuit should also be tuned. The closed oscillating circuits of both figs. 5 and 6 of the Stone patent are stated to be in tune with each other. To one skilled in the art, Stone's patent contemplated having all four oscillating circuits in tune or accord with each other.

The Stone patent drawing shows none of the condensers or inductances in any of these oscillating circuits to be adjustable, yet one skilled in the art at the time knew how to adjust any or all of them to obtain the desired resonance in the open and closed circuits. The Stone drawing did not show the open circuits provided with a tuning coil because it sometimes represented an embodiment in which the open circuit was adapted to receive simultaneously several frequencies and it could not be tuned to each.

LIV. The quotations from lines 16-20 of page 2 and lines 62-66 of page 6 of the Stone specification were inserted by the amendment of April 8, 1902, after the application was filed in the Patent Office.

As filed in the Patent Office, the invention of the Stone application was directed to obtaining a simple wave instead of a complex one in the transmitted signal. It was Stone's belief that the early apparatus for Hertzian-wave signalling gave complex waves where the oscillations were generated in the open circuit. To avoid this difficulty Stone generated his oscillations in a tuned closed circuit inductively coupled to the open circuit. Other precautions taken by Stone included the avoidance of substantial hysteresis losses and the use of an inductance in a circuit which was large compared to the mutual inductance between coupled circuits, for the purpose of obtaining simpler waves and lessening the mutual inductive effect upon tuning. Marconi's specification is silent upon the mutual inductive effects of the coupled circuits upon tuning, and it is not apparent that Marconi appreciated the necessity for loose coupling to get the best operation. Stone did appreciate the disadvantage of mutual inductive effects of the coupled circuits upon their tuning and suggested the large additional inductance to reduce this effect. Many of the apparatuses used by the United States contained this additional inductance in the open circuit. Both Stone and Marconi obtained free oscillations at the transmitter in a tuned closed circuit. By free oscillations is meant that their frequency was determined by the constants of the circuit in which they were generated. The Stone application as filed impressed these oscillations upon the open circuit, and therefore used "forced" oscillations in the open circuit of the transmitter, that is, the frequency of the oscillations in the open circuit was deter-

mined by the frequency of the oscillations in the closed circuit.

The effect of forcing vibrations upon a tuned and untuned circuit may be likened unto the effect of a tuning fork upon a stretched cord in a viscous medium. When the cord is vibrated by the tuning fork it has the same period as does the fork regardless of whether such period be that of [fol. 45] the natural period of the cord, but when the fork vibrations are in tune with the natural period or fundamental of the cord, then the amplitude of vibrations in the cord is a maximum. Marconi wanted his open and closed circuits to be tuned to the period of the impressed or forced oscillations, whereas Stone's application as filed was primarily concerned with having the closed circuits in tune at both stations. The advantage in having open and closed transformer circuits in tune at both transmitting and receiving stations not used for radio signalling was known to those skilled in the art before Stone filed as is shown by Tesla #645576 and such advantage for radio signalling was known to Stone as is shown by his letters to Baker referred to in finding LV.

The British patent of Marconi #7777, of 1900, corresponding to the patent in suit had the provisional specification filed April 26, 1900, the complete specification filed February 25, 1901, the complete specification accepted April 13, 1901, the complete specification and drawing printed and placed on sale May 4, 1901, and the patent granted June 25, 1901. No satisfactory evidence of knowledge or conception of the Marconi invention in Europe prior to the filing of the British patent #7777 of 1900, has been shown.

Exhibit R-3, a certified copy of the file wrapper of the Stone patent #714756, and exhibit 34, the British patent #7777 of 1900, are by reference made a part of this finding.

LV. Stone conceived the idea of having all four oscillating circuits of his figs. 5 and 6 tuned to the same frequency, at least as early as June 30, 1899. The letter from Stone to Baker, dated June 30, 1899, disclosed the wiring diagrams, reproduced on page 35, the top two figures of which are substantially the same as figs. 5 and 6 of the patent.

This letter stated:

"Instead of utilizing the vertical wire itself at the transmitting station as the oscillator, I propose to impress upon this vertical wire oscillations from an oscillator, which oscil-

lations shall be of a *frequency corresponding to the fundamental of the wire.* Similarly at the receiving station I shall draw from the vertical wire only that component of the complex wave which is of the lowest frequency.

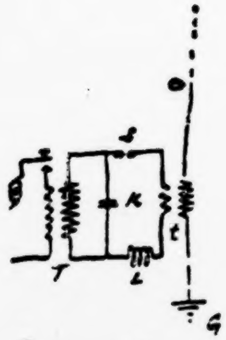
"*If now the fundamental of the wire at the receiving station be the same as that of the wire at the transmitting station,* then the receiving station may receive signals from the transmitting station, but if it be different from that of the transmitting station it may not receive these signals. * * * *The tuning of these circuits one to another and all to the same frequency* will probably be best accomplished empirically, though the best general proportions may be determined mathematically." (Italics ours.)

The Stone letter to Baker of July 18, 1899, in reference to his invention mentioned in the letter dated June 30, 1899, states:

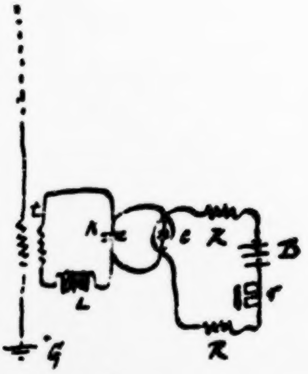
"The current in the vertical wire in my system may therefore be represented by a simple harmonic * * * and if the *period of this impressed force be the same as that of the fundamental of the vertical wire,* then it may be represented by * * *.

"I place the coherer at the receiving station in a resonant circuit tuned to the periodicity p. Under these circumstances the coherer will be operated by the signals sent from [fol. 46] the sending station described, but if a second sending station develops radiations of periodicity p_1, materially different from p, then the receiving apparatus will not be affected by these radiations, since the circuit in which the coherer is located is practically opaque to these radiations or more properly speaking, to the current which these radiations are capable of exciting.

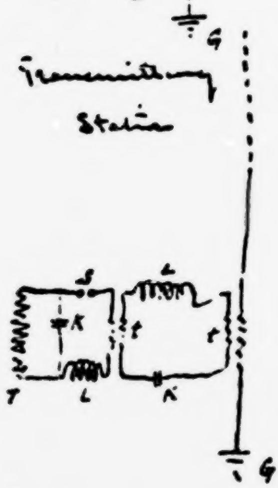
"The first transmitting circuit shown in my letter to you of June 30 is practically the same as that employed by Tesla for the production of high-frequency currents except that I place an inductance coil L in the circuit to give additional means of tuning and to swamp by its greater inductance the reactions from the induction coil t which would tend to make the oscillations multiperiodic instead of simple harmonic. The inductance of this coil should be made large compared to the inductance of the primary of t. *The use of an auxiliary inductance coil for the purpose of rendering the oscillations simple harmonic in the case of circuits con-*



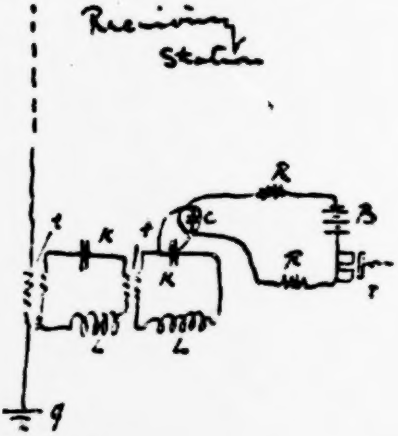
Transmitting Station



Receiving Station



Transmitting Station



Receiving Station.

nected with other circuits as described above, was first made by me and I have elsewhere given a mathematical demonstration of the fact that it accomplishes that purpose * * *. At the receiving station the coil *L* and the condenser *k* form a resonant circuit which is attuned to the frequency of the [fol. 47] current developed at the transmitting station. Again the inductance of the coil *L* should be made large compared to the inductance of the secondary of the induction coil *t* at the receiving station in order to obtain well defined resonance to a single frequency * * *.

"In the second set of transmitting and receiving stations shown in my letter to you of June 30 ultimo, everything is the same as that shown in the first two diagrams except that an additional resonant circuit attuned to the same frequency as the others is interposed between the vertical wire and the transmitting and receiving apparatus for the

purpose of additionally sifting out the undesired harmonics." (Italics ours.)

The Stone Tel. & Tel. Company was organized in December 1901 or January 1902 and it manufactured radio apparatus under this Stone invention.

LVI. Marconi, in order to obtain his patent, canceled some of his former claims when they were rejected on the Stone patent #714756. Marconi's former claims 4, 5, and 7, which were canceled after being rejected on this Stone patent, read as follows:

"4. At a transmitting station employed in a wireless telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to a condenser circuit discharging through a means which automatically causes oscillations of the desired frequency, such condenser circuit and the open circuit being in electrical resonance with each other, substantially as described.

"5. At a transmitting station employed in a wireless telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to a condenser circuit discharging through a means which automatically causes oscillations of the desired frequency, such condenser circuit and the open circuit being in electrical resonance with one another; an induction coil, the secondary of which includes the condenser aforesaid, a source of energy included in the primary winding of said coil, a means for varying the circuit of said primary winding, substantially as described.

"7. At a transmitting station, employed in a wireless telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected in a series with an adjustable condenser, and with a means which automatically causes oscillations of the desired frequency, substantially as described."

No effort by appeal or argument was made by Marconi to traverse the ruling of the examiner as to the propriety and pertinency of this Stone patent.

LVII. It was within the skill of those versed in the art to tune an open oscillating circuit such as that disclosed by the Stone patent #714756 or the Tesla patent #645576 by means of an adjustable inductance according to the teaching of the Lodge patent #609154, as well as by varying the length of the elevated conductor to control the distributed inductance and capacity. Stone did not intend to tune by [fol. 48] adjustment of the distributed inductance or capacity, as stated in lines 32-36 of page 9, where the patent states:

"and I wish it understood that I here disclaim any system employing distributed inductance and capacity as a means for tuning the resonant circuits described in this specification."

It was within the ability of those skilled in the art to tune the open circuits of the Stone patent transmitter and receiver by the use of a variable inductance, either an inductance constituted by the transformer winding or by a variable inductance in addition to the transformer winding. Stone was the first to teach the advantage in having a separate tuning inductance in addition to the transformer winding in order to make the inductance of the coupled tuned circuits large compared to their mutual inductance for use in Hertzian-wave signalling, as stated in lines 84-98 of page 5 of the patent and embodied in the Stone application when filed:

"The principle may for the present purpose be stated thus—that when two simple oscillators, each such as that shown in fig. 1, are inductively associated with each other, as in fig. 3, the system is a system of two degrees of freedom, and the natural period of oscillation of each simple circuit is modified by the presence of the other; but if the proportions of the circuits be such that the product of the inductances of the two circuits is large compared to the mutual inductance between the circuits the natural period of oscillation of each of the circuits becomes practically the same as if the circuits were isolated."

The Stone patent #714756 having pointed out the desirability for tuning the open transmitter circuit to the period of the closed transmitter circuit, it was obvious to one skilled in the art that open and closed receiver circuits should also be tuned to accord with each other and with the transmitter tuned circuits. It was also apparent that both the receiver circuits should be tuned in the same way, i. e., by the use of tuning inductances in addition to the transformer. The feature of a separate tuning inductance in any circuit inductively coupled to another was not novel with Marconi, but was, to one skilled in the art, disclosed in the Stone patent and was embodied in the Stone application when filed.

LVIII. The phraseology of claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 17, 18, 19, and 20, of Marconi #763772 relates to the same subject matter as is disclosed by the Stone patent #714756 as granted.

LIX. The phraseology of claims 2, 13, 18, and 19, of Marconi #763772 not being limited to the open and closed receiving circuits being in tune or resonance with each other, is directed to an arrangement of apparatus that was within the ability of one skilled in the art after Marconi's prior patent #627650.

LX. The terminology of claim 16 of the Marconi patent #763772 is directed to a combination of elements which is new and useful.

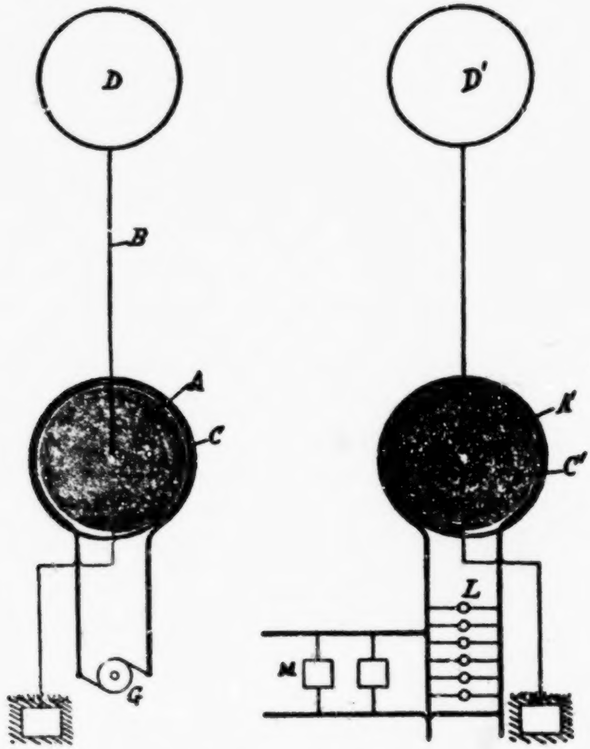
The tables on page 4 of the specification thereof indicate that the purpose of the condenser connected in shunt with the primary winding of the transformer of the receiver, is to enable the electrical periodicity or tuning of the open circuit of the receiver to be altered.

LXI. The phraseology of claims 1 and 3 not including an oscillating transformer nor the open and closed circuits being tuned, is directed to an apparatus such as that shown [fol. 49] by fig. 4 of the Lodge patent in suit. Claim 2 relates to fig. 12 of the Lodge patent in suit when a condenser *w* is used in circuit with the coherer. Claim 2, not being limited to the open and closed circuits being in tune nor to the variable inductance being in addition to the transformer primary winding, is directed to the apparatus shown by fig. 13 of Lodge. All of the loading

coils or inductances in the open circuits were intended to be adjustable by Lodge in order to syntonize or tune such open circuit.

LXII. Neither the British patent to Braun #1862, of 1899, nor the British patent to Braun #12420, of 1899, describes an apparatus having open and closed oscillating circuits in the transmitter and receiver which are to be tuned to accord with each other.

The United States patent to Tesla, #645576, patented March 20, 1900, on an application filed September 2, 1897, relates to a system of transmission of electrical energy through space.



As shown in the single figure of the drawings, reproduced above, the transmitter of this system comprises an elevated conductor or wire *B* with a capacity element D mounted at its upper end. This elevated conductor is connected with one end of the secondary *A* of an oscillation transformer; the other end of which is grounded. The primary

C of this transformer is connected with a source of high frequency oscillations *G*.

The receiving system also comprises an elevater conductor having a capacity element at its upper end *D'* con-[fol. 50] nected with one end of the primary winding *A'* of an oscillation transformer, the other end of said winding being grounded. The secondary of this receiving oscillation transformer is shown as connected to current using instrumentalities *L* and *M* defined on page 3, lines 24, 25, and 26 of the Tesla specification as "lamps *L*, motors *N*, or *other devices for utilizing current.*" While the specific disclosure of the drawings is illustrative of a continuous radiation and reception of energy through space, the Tesla specifications on page 5, lines 30 to 31, state that the method of energy transmission "will obviously have many other valuable uses", as "*for instance when it is desired to transmit intelligible messages to great distances.*"

In view of such statement it would be within the knowledge of those skilled in the art to interrupt the continuous generation of high frequency energy in the transmitting system by means of a telegraph key, and to substitute for the current receiving instrumentalities disclosed in connection with the receiving system, a radio signal detector device.

The Tesla patent on page 4, lines 26 to 28, refers to the fact that the primary and secondary circuits in the transmitting apparatus are "carefully synchronized" and further on the same page (lines 40 to 45) states that "the results were particularly satisfactory when the primary coil or system *A'* with its secondary *C'* was carefully adjusted so as to vibrate in synchronization with a transmitting coil or system *A C.*" Such phraseology instructs those skilled in the art that the open and closed circuits of the transmitting system and the open and closed circuits of the receiving system, of the Tesla patent, should be in resonance with each other, or, in other words, that all four circuits should be in resonance.

Such teaching is further implied in Tesla patent #649621, based on a divisional application of the above-named Tesla patent in which it is stated, beginning with line 97, page 1, that "it will be readily understood that when the above-prescribed relations exist the best conditions for resonance between the transmitting and receiving circuits are attained,

and, owing to the fact that the points of highest potential in the coils or conductors *A A'* are coincident with the elevated terminals the maximum flow of current will take place in the two coils, and this, further, necessarily implies that the capacity and inductance in each of the circuits have such values as to secure the most perfect condition of synchronism with the impressed oscillations."

LXIII. The receiving apparatus of the Kilbourne & Clark Company, shown in exhibit 95, and the receiver made by the Telefunken Company, illustrated in exhibit 79, each has apparatus coming within the terminology of claim 16.

Fleming Patent #803684

LXIV. The invention of the Fleming patent #803684 relates to a substantially inertialess rectifier that is suitable for use as a part of a detector with very high frequencies encountered in radio signaling, to permit the use of a direct current galvanometer to indicate the presence of the signals. The drawing of the Fleming patent is reproduced on page 40. [fol. 52] In fig. 1 of the foregoing drawing, *n* is the aerial wire of the receiving station connected to the ground *o* through the primary winding *m* of the transformer whose secondary winding *k* is located in a closed circuit containing a two-electrode vacuum tube and a galvanometer or other indicator *l* of the received signal. The tube comprises a glass bulb *a* provided with a carbon filament *b* like that of an incandescent lamp operable at six or eight volts to consume two to four amperes. An aluminum cylinder *c* is suspended by platinum wires *d* from the glass bulb. The battery *h* heats the filament *b* through the leads *f*, *e*, to a temperature near 1,700° C. in a good or very high vacuum, with the result the current will flow only in one direction between the filament and the cold electrode *c*. The radio-frequency impulses received in the antenna are induced in the closed circuit of the transformer secondary winding and are rectified by the vacuum tube with the result that half of the radio-frequency waves in fig. 1 are lost and half pass through the vacuum tube and are effective to actuate the direction-current galvanometer *l*. In fig. 2 the closed circuit contains two tubes oppositely connected so that the differential galvanometer *q* receives both halves of the rectified waves and no large amount of energy is lost as is the case in fig. 1. In fig. 3 the use of a number of these

Fig. 1.

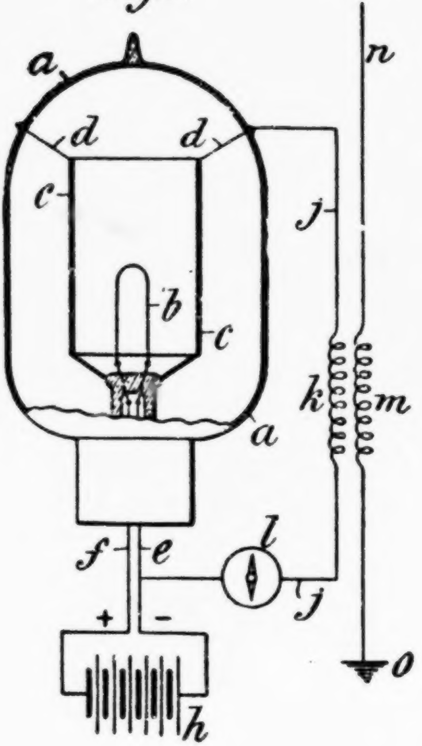


Fig. 2.

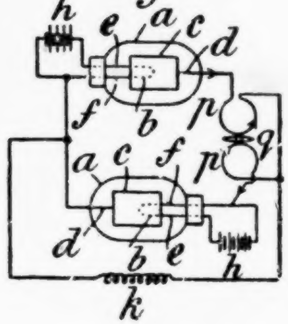
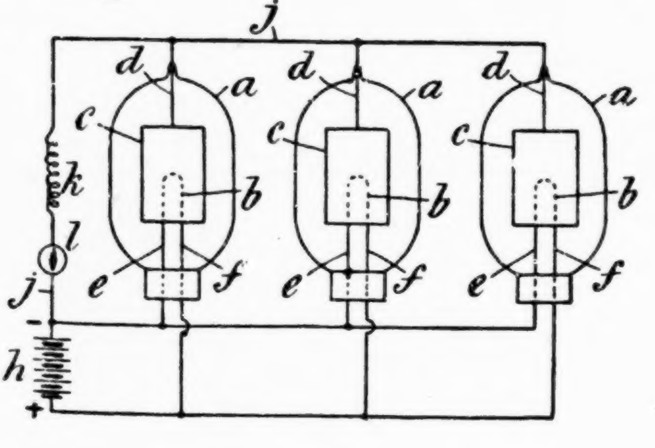


Fig. 3



one-way valves is shown in parallel to increase the possible current flow. Negative electrons are given off by the hot electrode to constitute the current flow in only one direction.

LXV. The claims in suit are numbered 1 and 37:

"1. The combination of a vacuous vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, and a circuit outside the vessel connecting the two conductors.

"37. At a receiving station in a system of wireless telegraphy employing electrical oscillations of high frequency a detector comprising a vacuous vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, a circuit outside of the vessel connecting the two conductors, means for detecting a continuous current in the circuit, and means for impressing upon the circuit the received oscillations."

On November 17, 1915, the assignee, Marconi Wireless Telegraph Company of America, disclaimed the combinations of elements in certain claims, including claim 1, "except as the same are used in connection with high-frequency alternating electric currents or electric oscillations of the order employed in Hertzian wave transmission." The disclaimer also eliminated the words "whether of low frequency or" in page 2, lines 32 and 33, and "either", in line 98 of page 2, and also the words "or low-frequency alternating currents of", in lines 98 and 99 of page 2 of the patent.

In claim 1 the vacuous vessel is the exhausted glass tube *a*, the two conductors are the filament *b* and the cold cylindrical electrode *d*. The means for heating one of the conductors is the connected battery *h*, and the circuit outside the vessel is that through the galvanometer and transformer secondary winding *k, j, d, c, b, e, l.*

In claim 37 the receiving station is shown by fig. 1 to include the vacuum tube as a detecting rectifier and a galvanometer for detecting or indicating the presence of a continuous or unidirectional pulsating current. The antenna circuit and the transformer connections are the means [fol. 53] for impressing upon the circuit the received oscillations. By the term "detector" Fleming's specification

meant to one skilled in the art a device adapted to make feeble high-frequency impulses measurable with an ordinary direct-current mirror-galvanometer, or in other words, the term "detector" includes both the rectifier tube and the direct-current indicator of the rectified current. The term as used in the Fleming patent did not include all apparatus associated with the detector tube and did not include any amplifying tube or tubes.

LXVI. The earliest date available to Fleming for this invention is November 16, 1904, the filing date under the International Convention for the corresponding British patent #24850 of 1904.

The file wrapper of this Fleming patent has not been offered in evidence.

Exhibit 77, the British patent corresponding to the United States patent in suit, is by reference made a part of this finding.

LXVII. The Fleming two-electrode valve went into use in a limited way; less than seven hundred Fleming valves having been shipped to various ship and store stations by plaintiff between 1910 and 1915. These Fleming valves were more sensitive than some types of crystal detectors and less sensitive than other types.

In 1914, the plaintiff company began to have manufactured for it and sent to the stations to which the valves had been sent originally, crystal detectors with adaptors so the same could be used in the sockets of the receiving sets in lieu of the Fleming valves.

There is no satisfactory evidence of any infringing use of the two electrode tubes by the United States.

LXVIII. It was not the custom of the plaintiff to mark all of its name plates with notice of this Fleming patent. Name plates of exhibits 14 and 31, used on receivers, contained no notice of this patent. Except as mentioned in finding XII, no notice to the United States of the Fleming patent and its infringement has been satisfactorily proven to have been given by the plaintiff to the United States before the commencement of this action.

In January 1914 a release was proposed by the United States from all patents granted to the plaintiff prior to

1907 and such proposed release was declined. The Fleming patent and the other patents in suit were not specifically mentioned in the proposal.

LXIX. The prior art relied upon to show anticipation and lack of invention includes:

United States patent to Edison #307031 October 21, 1884;

French patent to de Valbreuze #328687 May 7, 1903;

The Electrician, London, February 21, 1890, pp. 393-395;

Proceedings of the Royal Society, London, 1890, vol. 47, pp. 118-126;

Philosophical Magazine, London, 1899, vol. 48, pp. 547-566;

Proceedings of the American Institute Electrical Engineers, November 1897, vol. 14, pp. 31-35;

Philosophical Magazine, London, 1898, vol. 46, p. 528;

Proceedings of Cambridge Philosophical Society, London, March 1901, vol. 11, p. 286;.

Philosophical Transactions of the Royal Society, London, March 1903, vol. 11, p. 497;

[fol. 54] Proceedings of Cambridge Philosophical Society, London, 1897, vol. 9, p. 244;

Proceedings of Cambridge Philosophical Society, London, 1897, vol. 9, p. 333;

Proceedings of Cambridge Philosophical Society, London, April 1903, vol. 5, p. 429;

Philosophical Magazine, London, March 1903, vol. 5, p. 345;

Annalen der Physik, Berlin, April 20, 1904, pp. 425, 467;

Physikalische Zeitschrift, Berlin, October 20, 1904, pp. 680, 681;

United States patent to Hewitt #781001, January 31, 1905, filed May 16, 1902;

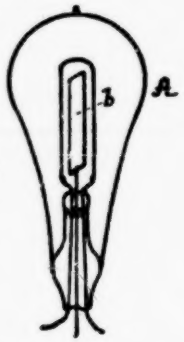
United States patent to Hewitt #781002, January 31, 1905, filed May 16, 1902.

Exhibits J, O, P, I-1, K-1, M-1, O-1, P-1, Q-1, R-1, S-1, T-1, U-1, V-1, W-1, X-1, Y-1, Z-1, A-2, and B-2 are by reference made a part of this finding.

LXX. The Edison patent #307031 showed a two-electrode vacuum tube in which one of the conductors is a heated filament adjacent to but not touching the other conductor, and provided with a circuit outside the vacuous vessel connecting the two conductors. Edison believed the

current flow through his tube to be proportioned to the degree of incandescence or candle power of the filament and connected his tube in circuit with a galvanometer or relay for indicating or controlling conditions in the filament circuit. Fig. 4 of the Edison patent set out below illustrates the lamp with a heated filament and within the loop of the filament the plate, marked *b*. The heated filament is one of the conductors mentioned and the plate is the other. The wire leading downward from the plate in the illustration is continued in a circuit shown in another figure of the patent which connects the two conductors. Current passed from the heated filament to the cold plate and for this reason Edison's tube is referred to as the two-electrode tube.

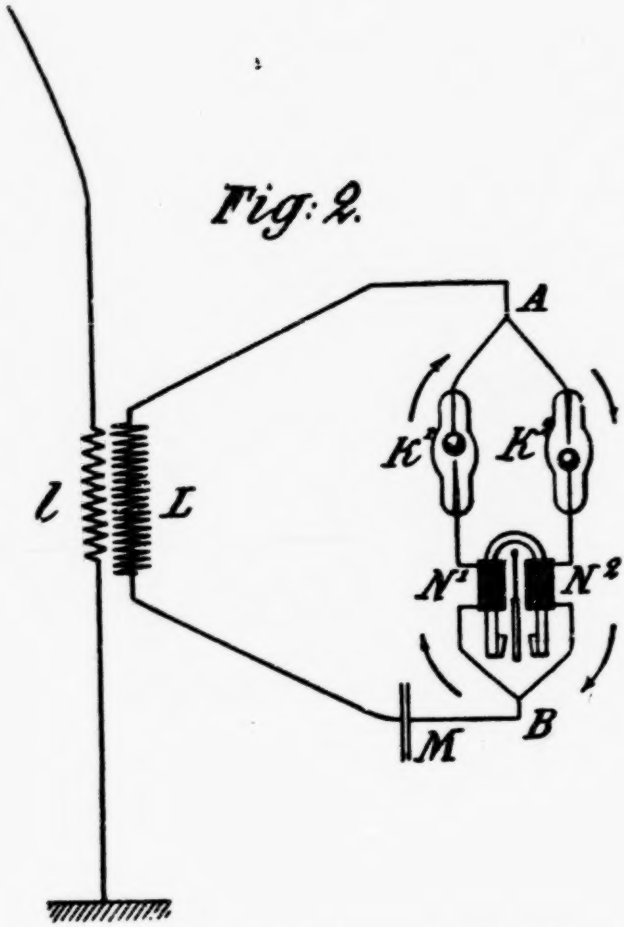
Fig. 4.



Long before the application for the Marconi patent was made the Edison two-electrode tube was investigated and experimented with in great detail.

The French patent to de Valbreuze #328687 did not have a vacuum tube with heated filament but did propose a vacuum tube with two cold electrodes for use with radio frequencies as a rectifier. This patent, by fig. 2 herein reproduced, shows an open oscillating circuit through the primary *l* of the transformer. The secondary *L* is con-[fol. 55] nected oppositely through two vacuum tubes K^1 and K^2. The current then flows through the coils N^1 and N^2 of a sensitive polarized relay, somewhat after the manner of fig. 2 of Fleming and thence through a condenser *M*. This patent has date of May 7, 1903, and was published July 18, 1903, over a year before the filing date of Fleming's British patent.

Fig: 2.



LXXI. The proceedings of the Royal Society, London, 1890, volume 47, pp. 118-126, contained an article by Professor Fleming in which he described the unilateral conductivity between the hot and cold electrodes in a vacuum tube of the general type of the Edison patent mentioned above and showed that the current flowed only in one direction when an alternating current was used in connection with a lamp of an Edison apparatus. He also discussed the flow of current from the hot negative terminal of the lamp to the cold electrode of the plate, with the result that negative electricity flowed from the plate into an additional circuit connected with the lamp.

[fol. 56] At a meeting of the American Institute of Elec-

trical Engineers at New York in 1897, Clark Howell described, in a paper read, the Edison effect and again pointed out that an alternating current passing through the lamp of an Edison apparatus produced in a branch circuit a unidirectional current, and this fact was commented upon at the same meeting by Dr. Kennelly.

These papers by Fleming and Howell and the early Edison patent #307031 anticipate claim 1 of the patent in suit before the disclaimer was filed. This publication was made by Professor Fleming about fifteen years before he filed his application for the patent in suit and about twenty-five years before the disclaimer as to claim 1 was filed. Professor Fleming knew that a combination of apparatus such as is called for by claim 1 of the patent as issued, to be old, and he did not file or cause to be filed the said disclaimer until about ten years after the patent issued.

In the Philosophical Magazine of December 1899, volume 48, pp. 547-566, Professor J. J. Thompson showed that the mass of the negatively charged particles emitted from the heated filament in the vacuum tube was only a small fraction of the size of the hydrogen ion, and these were the smallest then known particles.

LXXII. The inventive monopoly expressed in the Fleming patent in suit after the disclaimer had been filed therein, does not include, as features of novelty, the unilateral conductivity of Edison's two-electrode tube; the fact that the negative electrons emitted by the heated filament were of very small mass; the fact that the electron stream could be controlled by the potential of the cold electrode; or that the valve was an appropriate rectifier for alternating current, all of which facts were known to those skilled in the art more than two years prior to November 16, 1904, the earliest date available to Fleming for his invention.

The Fleming patent, as modified by the disclaimer, does not include all uses for the electron emissions from the heated electrode, nor all uses for such emissions in connection with radio frequencies, but relates only to a rectifying use for such emissions in connection with currents of radio frequencies.

What the invention did include, to one skilled in the art, was an appreciation of the desirability of using the Edison two-electrode vacuum tube as a rectifier for radio frequencies, where other types of rectifiers were not appropriate for such high-frequency oscillations. Professor Fleming found a new application for Edison's two-electrode vacuum tube.

LXXIII. The Fleming patent as modified by the disclaimer filed therein, is directed to a new and useful use of an old structure, i. e., the two-electrode tube, but in a short time it was practically superseded by apparatus using the three-electrode tube.

LXXIV. A two-electrode tube of the Edison or Fleming type may be made to produce oscillations, provided an independent source of electric energy is inserted in the exterior circuit connecting the cold electrode to the filament; this source of energy has a certain selected potential, the value of which varies with the characteristics of the tube used, and a sufficient residual amount of gas is present in the tube to permit an ionization effect. Such oscillations [fol. 57] as are thus obtained are critical and unstable, and no satisfactory evidence has been introduced to show that the Fleming, or two-electrode tube, was ever commercially operated in this manner.

A two-electrode tube may also be made to oscillate or amplify by inserting an independent source of energy in the exterior circuit connecting the cold electrode to the filament, and by locating the tube adjacent an electrostatic or electromagnetic field in such manner that the field exerts a control action on the electron flow taking place within the tube. This was discovered subsequently to the use of a three-electrode tube as an amplifier.

The Fleming patent in suit does not disclose or teach those skilled in the art that the vacuous space in the tube should have a definite residual gas content; that an exterior source of electric energy should be located in the circuit between the cold electrode and the filament, or that the potential of this source should be varied in accordance with the individual characteristics of the tubes. Nor does the patent in suit instruct those skilled in the art how to control or vary the electron flow within the tube in accordance

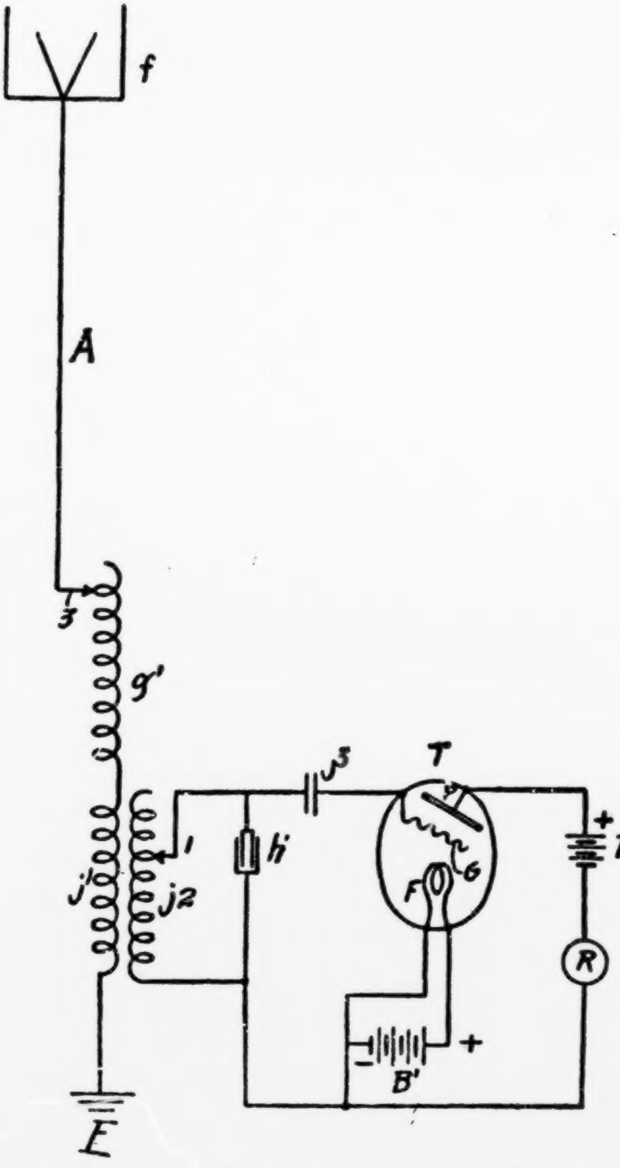
with an incoming radio signal in such manner as to produce an amplified reproduction of such signal in the exterior circuit connecting the plate and filament.

The Fleming tube does not possess any inherent ability to generate radio oscillations or to amplify them and can be made to do so only by circuit connections never appreciated by the inventor of the patent in suit. The United States operated no two-electrode tubes as either amplifiers or oscillators by either of the two above-mentioned methods.

LXXV. All alleged infringements comprise use of the three-electrode tube and sales of such tubes and apparatus for using them.

One such alleged infringement is the audion detector connected as shown in exhibit 83, reproduced on page 47.

The open antenna circuit fAg^1j^1E is inductively coupled to the tuned closed oscillating circuit j^2h^1. The grid G and filament F of the three-electrode tube T are connected across the condenser h^1 and in series with the condenser j^3. Small variations in potential on the grid control the electron flow to the plate and cause a larger variation in potential at the plate, which corresponds with the grid potential variations. As soon as the grid and its connected plate of condenser j^3 become negatively charged, rectification of the full high radio-frequency waves ceases. The only rectification taking place after that is of a small portion of the radio-frequency wave necessary to replace the loss in negative charge on the grid condenser through leakage. Due to the grid condenser and leakage through residual gas, the potential of the grid G varies according to the audio frequencies and not fully with radio frequencies as intended by Fleming for his cold electrode. In later detector tubes with less residual gas it was customary to have a very high resistance arranged in shunt with the grid condenser, so proportioned that the grid potential varied accurately with audio frequencies yet very little with radio frequencies. Such a grid leak is shown, for example, in exhibit 114. Looked at in another way, the grid condenser and properly [fol. 58] desiged leakage path do not allow the radio oscillations to be fully impressed on the tube and only allow the audio-frequency waves to pass and become impressed upon the plate circuit.



DeForest Audion, Used by Navy (Exhibit 83)

The variation in plate potential is due to the control of the electron discharge from the filament effected by the grid. This type of electron control by a third filament within the field of electron discharge was not appreciated by Professor Fleming and causes the three-electrode tube when used as a detector to operate in a different manner from the use of the two-electrode tube discovered by him.

[fol. 59] The audio variations in potential impressed upon the grid appear upon the plate in magnified or amplified form, and thus the tube in exhibit 83 amplifies as well as detects. Where the Fleming patent contemplated detection by rectification of the full radio or high-frequency oscillations impressed upon an indicator adapted to register the strength of the rectified unidirectional pulsating current, the three-electrode tube in exhibit 83 detects by substantially suppressing the high-frequency oscillations and amplifying principally the low or audio-frequency oscillations.

The apparatus shown by exhibit 83 is for use at a receiving station in a system of wireless telegraphy employing electrical oscillations of high frequency, and has a detector comprising a vacuous vessel with three conductors adjacent to but not touching each other in the vessel, and means for heating one of the conductors. The only circuit outside of the vessel connecting any two conductors and containing a means for detecting currents in this circuit, is the plate circuit containing the telephone receiver *R*.

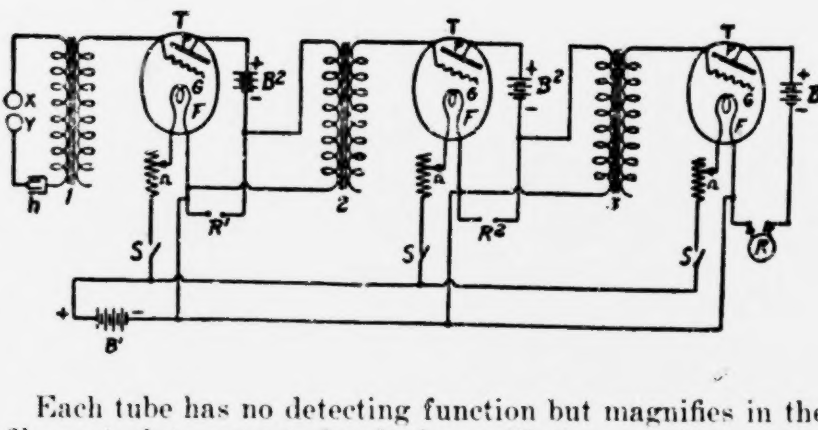
This telephone receiver is not so much a means for detecting or indicating a continuous current in its circuit as it is a means for detecting the presence of audio-frequency changes in such direct current. The telephone receiver would not indicate the presence of unidirectional current of constant strength pulsating at radio-frequencies as would the galvanometer in the Fleming patent. Having in mind that the plate circuit is the only one which might be regarded as the output circuit because it contains an audible indicator, it may be further seen from exhibit 83 that there is no means for impressing upon this outside circuit the full received oscillations of radio frequency. The grid circuit constitutes a means for impressing upon the plate circuit mainly only audio oscillations received and not the radio or high-frequency oscillations contemplated by claim 37, because the grid condenser substantially suppresses these received high-frequency oscillations and impresses no large part of them upon the plate circuit. While a small portion of the received high-frequency oscillations may be so impressed upon the plate circuit and require a condenser across the telephone receiver, any such small part of the radio-frequency oscillations not suppressed hardly constitute the full received radio-frequency oscillations contem-

plated by the patent as being impressed upon the tube and its outside circuit.

To summarize, the three-electrode tube of exhibit 83 functions differently from the tube in the Fleming patent because (*a*) it has a third electrode located within the tube to effect a control of the electron stream, which electrode is connected to an input circuit separate from the output circuit, which latter circuit contains a local source of energy, and a radio signal impressed upon the input circuit is reproduced in amplified form in the output circuit; and (*b*) the tube in exhibit 83 is used to supply the plate or output circuit principally with low or audio-frequencies since the grid condenser suppresses the major part of the received high frequency radio oscillations, and prevents them from being impressed upon either the grid or the plate circuit containing the audible indicator.

Exhibit 114 is by reference made a part of this finding.

[fol. 60] LXXVI. Another alleged infringement includes the use of three electrode tubes connected for amplifying purposes as shown by exhibit 85, here reproduced:



Each tube has no detecting function but magnifies in the filament plate output circuit the oscillations applied to the input or filament grid circuit. There is no detecting action within the meaning of the Fleming patent even if the amplifier be used in connection with a detector and used with either radio or audio frequencies. The device illustrated being intended for use with audio frequencies, as is evidenced by the presence of the iron transformer cores, is

not for use in connection with high frequency oscillations as contemplated by the disclaimer to claim 1, and in this exhibit there is no detector nor any means for detecting the continuous or unidirectional current in a circuit connected to a tube having high frequency oscillations impressed thereon, as called for by claim 37. When the three-electrode tube is used for purposes of amplification it functions in a radically different manner from any use contemplated by Fleming.

LXXVII. The properties of the three-electrode tube are such that when it is utilized as a detector tube in a circuit arrangement involving no feedback or regeneration, it gives a signal response approximately 50% better than a good crystal detector.

Where a three-electrode tube is utilized in a receiving circuit of a type in which a feedback or regenerative action takes place, the signals are twenty to thirty times stronger than can be obtained in the nonregenerative circuit due to the fact that the inherent amplifying properties of the three-electrode tubes are more completely utilized.

When a plurality of three-electrode tubes are 'tilized in a radio receiving apparatus in which both radi requency and audio frequency amplification are utilized, the resultant amplification is of such high magnitude, that radio signals from Europe can be received in this country by the use of indoor antenna.

The three-electrode tube was a valuable contribution to the radio art in the manner stated above and represented a vast improvement over the Fleming two-electrode tube.

[fol. 61] LXXVIII. The oscillators of exhibit 116 also function in a different manner from that possessed by the use of the two-electrode tube discovered by Fleming. Neither the two-electrode tube nor its use discovered by Fleming possesses any inherent ability to oscillate in a manner susceptible of commercial use. The oscillators have no detecting function of claim 37.

Exhibit 116 is by reference made a part of this finding.

LXXIX. The regenerative receiver of exhibit 114 (referred to in finding LXXV) functions like the receiver of exhibit 83 except that it has an added amplifying function by means of the coil j^3 in the plate circuit impressing further audio potential changes upon the grid circuit.

The direction finders of exhibit 115 are like the regenerative receivers of exhibit 114 except that there are two antenna primary circuits, one open and one closed, but both coupled to the same secondary oscillating circuit.

Exhibit 115 is by reference made a part of this finding.

LXXX. The three-electrode tube may be connected for use as an amplifier, oscillator or detector or combinations of some of these. A number of three-electrode bulbs were purchased by the United States for such uses as it saw fit to give them.

LXXXI. Before the disclaimer was filed on November 17, 1915, the three-electrode tube had been invented, as had also its connections for use as detector, amplifier, and oscillator. The United States had ordered and used substantial quantities of three-electrode vacuum tubes as detectors and amplifiers prior to November 17, 1915, when said disclaimer was filed.

LXXXII. Plaintiff has granted licenses to the following manufacturers:

(*a*) National Electric Signaling Company, dated October 5, 1914, under the Lodge and the Marconi four-circuit patents. This license terminated May 30, 1917;

(*b*) The National Electric Supply Company, dated July 14, 1914, and April 15, 1915, under the same two patents, and terminated January 24, 1916;

(*c*) Moorhead Laboratories, Inc., dated November 30, 1918, and April 30, 1919, under the Fleming patent, and terminated June 30, 1920;

(*d*) General Electric Company, dated October 22, 1919, releasing, under conditions, the General Electric Company's customers from any charge of infringement as to apparatus purchased from General Electric Company.

(*e*) The United States purchased from the plaintiff on November 26, 1918, certain apparatus and stations with a release of the apparatus so purchased, from any charge of infringement.

Exhibits 360, A-7 and B-7 are by reference made a part of this finding.

LXXXIII. It has been stipulated that the issue of reasonable compensation or damages and profits be postponed

until the determination by the court of the issues of validity and infringement of the various patents in suit.

[fol. 62] **Conclusions of Law**

Upon the foregoing special findings of fact, which are made part of the judgment herein, the court decides, as a conclusion of law—

(1) That the Marconi reissue patent #11913 has not been infringed by the defendant;

(2) That the Lodge patent #609154 is valid, and that any use of the combination described therein is an infringement, but that no recovery can be had by plaintiff for use of any such apparatus purchased or acquired prior to March 8, 1913;

(3) That the Marconi patent #763772 is invalid except as to claim 16 thereof, which is infringed by the apparatus specified in Finding LXIII and any other apparatus used by defendant coming within its terminology;

(4) That the Fleming patent #803684 has not been infringed by defendant.

Final judgment is reserved until the amount of reasonable compensation for damages or profits is determined in accordance with the stipulation of the parties.

Opinion

Green, Judge, delivered the opinion of the court:

The act of June 25, 1910, 36 Stat. 851, as amended by the act of July 1, 1918, 40 Stat. 705, confers upon the owner of a valid patent the right to bring suit in the Court of Claims against the United States to recover compensation for any infringement of the patent or patents by the Government. During the period involved in the suit the plaintiff was the owner of certain patents which are the basis of the suit herein, namely: Marconi Reissue, #11913; Lodge, #609154; Marconi, #763772; Fleming, #803684.

Each of these patents relates to electrical communication between different points without connecting wires, which is generally known as radio communication. It is alleged by plaintiff that all of these patents have in one or more respects been infringed by the defendant.

On behalf of the defendant it is alleged:

(1) That plaintiff has released the defendant;
(2) That plaintiff has assigned its claims herein;
(3) That the patents are invalid;
(4) That even if none of the above defenses are sustained, plaintiff cannot recover for the reason that the evidence fails to show that any of the patents have been infringed.

The questions that relate to plaintiff's right to maintain the suit will be taken up in their order. All questions relating to the validity and alleged infringement of the patents will be taken up in the order in which the patents were issued, each patent being considered separately.

It is contended on behalf of defendant that under the provisions of the contract of sale made by plaintiff to defendant of wireless and ship stations, as set out in Finding V, the suit should be dismissed as to all patents in suit except the Fleming patent #803684, it being conceded that the apparatus sold included the combinations set forth in the other patents. The finding shows that the contract released the defendant from the payment of any further sum "on account of its (plaintiff's) patent rights involved [fol. 63] in any of the apparatus hereby transferred." We think it obvious that the release applied only to the property sold and "transferred" by the contract which is not involved in the suit.

November 20, 1919, plaintiff sold to the Radio Corporation its factory, letters patent, including the letters patent here in suit, and certain land transmitting stations, reserving to itself:

"A claim against the United States Government arising from unlicensed use by and for the Government of the apparatus covered by the patents of the Marconi Company."

The agreement further provided that all amounts received in cash by the Marconi Company after paying expenses should "forthwith be paid to the Radio Corporation" which should issue therefor preferred stock, and it is argued that plaintiff's claim has been assigned and therefore no suit could be brought thereon. We do not think this follows. It is true that the ultimate effect of the agree-

ment was to enable the Radio Corporation to become the owner of all that might be recovered in this suit but it did not become the owner thereof until plaintiff had prosecuted the suit to judgment and assigned any judgment in its favor to the Radio Corporation. Up to that time the Radio Corporation merely had a contingent chose in action. It is suggested that after conveying the title to the patent and as to infringements reserving only the right to bring action against the defendant, plaintiff had lost the right to bring suit against the defendant but the general rule is that the right to sue for infringement rests with the one who was the owner of the patent at the time the infringement occurred. Some question might possibly arise as to the validity of the assignment to the Radio Corporation and with respect to the right of that company to sue for other infringements, but this is the most that can be inferred from the cases cited. We think it clear that in its transactions with the Radio Corporation plaintiff has done nothing to invalidate its right to sue for any infringement committed by the defendant prior to the time of the sale and this is all that is claimed.

The Marconi Reissue Patent #11,913

Guglielmo Marconi, an Italian scientist, is sometimes called the father of wireless telegraphy but he was not the first to discover that electrical communications could be made without the use of connecting wire. The theory upon which this art is based was first disclosed by Professor Maxwell of Cambridge as far back as 1865. Maxwell, however, did not propose any apparatus for developing its use, if indeed he had any idea that it might be made useful, and no practical demonstrations of his theory were made until Heinrich Hertz, between 1879 and 1890, discussed the Maxwellian theory and described apparatus for carrying it into effect in an article published September 21, 1888. The experiments which Hertz made public substantiated and amplified the theory of Maxwell. Hertz showed that circuits through which a current of high frequency electricity passed developed electrical disturbances in the form of waves which had many of the properties of light waves and that this radiant energy set up what might be called ether waves somewhat like sound waves which induced cur-
[fol. 64] rents in other circuits not connected by wire there-

with. His apparatus consisted of a transmitter so called because it transmitted the electric wave and a receiver so named because it was put into electric vibration by electric waves from the transmitter although it was not connected with the transmitter. The transmitter included a battery and an induction coil connected with an oscillator or radiator circuit. There was a gap in the circuit where two rods which were connected to the secondary terminals ended in polished metal balls in close proximity, all so arranged that when the current in the primary coil was interrupted there was a discharge of sparks across the spark gap which resulted in the radiation of the wave. To prove the existence of the wave and its transmission Hertz used a turn or loop of wire either in the form of a rectangle or a ring, the two ends terminating in metallic knobs separated by a minute gap. When the ring or loop was held near an active oscillator, electric impulses were set up which revealed themselves by minute sparks at the gap between the balls. Thus Hertz proved the existence of the waves and the fact that they could be transmitted, but he never succeeded in producing waves which were detectable except at a short distance. His experiments created great interest in the scientific world and other scientists took up his discoveries where he left off and carried them still further.

Nearly six years later, Sir Oliver Lodge, in 1894, wrote a series of articles in the "London Electrician" describing the original and later work of Hertz and explaining it by means of diagrams.

A number of distinguished scientists continued to experiment and develop theories with reference to the transmission of electric waves without wires and methods for accomplishing such a transmission. Among these were Popoff, Tesla, Crookes, Dolbear, and Edison. Some of these men took out patents as did Lodge, although his patent was later than the patent of Marconi, and it becomes necessary to consider the effect of their discoveries and disclosures upon the patent in suit.

Marconi applied for his first patent in 1896 and it was reissued under date of June 4, 1901. The reissue patent #11,913 relates to a "complete system or mechanism capable of artificially producing Hertz oscillations and forming the same into and propagating them as definite

signals and capable of receiving and reproducing, telegraphically, such definite signals; * * *."

The subject-matter of the reissue patent was extensively used until displaced by later improvements. The plan of this system is shown by figs. 10 and 11 of the patent, reproduced in Finding IX. The same finding also shows the form of the transmitter and the receiver, and explains the diagrams and the manner in which the apparatus worked. We do not think it necessary to repeat this explanation in the opinion.

The only claim of the reissue patent which is involved in this suit reads as follows:

"3. The combination, in an apparatus for communicating electrical signals, of a spark producer at the transmitting station, an earth connection to one end of the spark producer, an insulated conductor connected to the other end, an imperfect electrical contact at the receiving station, an earth connection to one end of the contact, an insulated [fol. 65] conductor connected to the other end, and a circuit through the contact, substantially as and for the purpose described."

Figure 10 illustrated in Finding IX is a diagram of the apparatus used in the combination.

Findings X, by reference to fig. 10, locates the essential parts of the combination of the transmitting station.

The original patent having been considered to be defective because some of the claims were thought to have covered apparatus employed by Prof. Popoff, changes were made in the claims with reference to the tube *j* in the transmitting station (see fig. 11). The original patent No. 586193 stated:

"The tube *j* may be replaced by other forms of imperfect electrical contacts, but this is not desirable."

In the reissue patent the meaning of this quotation was changed by omitting the words, "but this is not desirable." No satisfactory explanation of the reasons for this change in the scope of the description of the invention has been given.

It is urged on behalf of defendant that there was nothing new in any of the apparatus described in the patent and that the combination thereof involved no inventive skill and

presented no new discovery, but was one which could be perceived by a person skilled in the art and consequently no valid patent could rest thereon. Counsel for plaintiff vigorously dispute these contentions and call attention to the fact that new results followed from its use of the Morse code for signalling with Hertz waves to a greater distance than was previously thought possible. It should be noted in this connection that the combination of the Marconi patent appears to be the first one that went into practical and general commercial use for the purpose of communication through electric signals transmitted without wires.

When we consider the evidence it shows that there was nothing new in any of the individual elements of the apparatus described in claim 3 and while counsel for plaintiff in argument endeavor to show an infringement based on some one or more of these features we are clear that the combination alone was patentable and think a reading of the claim shows that nothing more was intended. If we are correct in this, it follows that if the defendant in the apparatus which it used omitted some element of the combination of the patent and introduced other and different elements instead having a different and useful effect, there would be no infringement of the patent.

Tesla, in 1893, disclosed a practical apparatus for generating and utilizing Hertzian waves. His sending apparatus is described in what is called the Martin book, introduced in evidence, and showed that he used a powerful alternating current generator inductively coupled to a lateral charging circuit containing a spark gap and a condenser, whereby oscillations were generated and this charging circuit was inductively coupled to a distributing circuit.

Popoff, in 1896, prior to the reissue of the Marconi patent, described a receiving apparatus for detecting Hertzian electric rays. The transmission station had an earth connection and he employed a coherer substantially identical with that alleged to be disclosed in the Marconi reissue patent. [fol. 66] It was this kind of a coherer that furnished the imperfect electrical contact referred to in the claim in suit. Tesla, Popoff, Crookes, and others fully appreciated the fact that their inventions and disclosures would in the future form part of a system for the transmission of wireless messages.

In the case of *Marconi Wireless Tel. Co.* v. *DeForest Wireless Tel. Co.* (138 Fed. 657, 671), Judge Townsend, as

we think, correctly disposes of any claim for originality based upon the separate features of the Marconi reissue patent. He said:

"If now we examine the patent in suit in the light of this discussion, we shall find that every element of the claims in suit is taken from the prior art. The signaling and receiving instruments are common to the various apparatus from Dolbear, in 1882, to Popoff, in 1895; the Morse key is specifically referred to by Dolbear, Edison, and Kitsee, and is suggested by Lodge; the spark-gap, invented by Hertz for producing the Hertz oscillations, is found in Lodge and Popoff; the 1891 Branley coherer or 'imperfect electrical contact', comprising a tube with filings, and its operation by means of a tapper, are elaborately explained in Lodge's lecture, and utilized by Popoff in his experiments; and 'choking-coils' are illustrated and described by Popoff. The 'insulated conductors', described and shown as comprising elevated plates suspended on wires, were shown in Dolbear, Edison and Kitsee."

Judge Townsend held in effect that the combination was patentable, but we shall not discuss the question of whether his conclusion in this respect is correct. In the case before him, a different kind of detector was used from any involved in the instant case. It must be conceded, however, that if his reasoning should be followed it would require us to hold that the apparatus used by defendant, which comprised a crystal detector with certain forms of transmitters and receivers, constituted an infringement of the Marconi reissue patent. In this conclusion we do not agree, but hold with Judge Veeder's decision in *Marconi Wireless Tel. Co. v. National Electric Sig. Co.* (213 Fed. 815), a case in which the issues so far as the Marconi reissue patent is concerned were exactly the same as those in the case at bar.

A determination of the question of infringement requires a comparison of the apparatus described in the patent with that used by the defendant. The particular features of the combination set out in plaintiff's patent which are alleged to be infringed are the imperfect electrical contact and the transmitter. The imperfect electrical contact shown in the patent in suit was a device known as a coherer, which was a detector of the electrical waves. The coherer or detector used by Marconi was a tube containing metal filings which

was placed in the circuit of the receiving station. When a weak high-frequency current was passed through this circuit, these metal filings tended to cohere and from this feature the name coherer was derived. The patent contemplated such a degree of imperfection in the contact of the particles in the coherer that the local-battery circuit which included it would be broken on tapping the coherer. Means [fol. 67] were provided for tapping the coherer and thus the current would be broken by the tapping and again restored by the high frequency effect.

None of the receiving sets used by the defendant, however, used a coherer similar to that described in plaintiff's patent. On the contrary, a device altogether different, and functioning in a different manner was used. In the apparatus of defendant there was no tube containing metal filings, nor was there any imperfect electrical contact. The device used is commonly known as a crystal detector. In the crystal detector the connection is made by a fine wire which completes the circuit by being brought into contact with a crystal also forming a part of the circuit. This crystal acts as a rectifier in the manner of a one-way valve, allowing much larger portions of the high-frequency waves to flow in one direction than in the other. This constituted a great improvement on Marconi's invention as was shown by the fact that in practice it rapidly displaced the coherer. Not only was it a better detector, but it also enabled speech or music to be heard and it is still used in some of the simpler forms of the modern "radio." It is urged on behalf of plaintiff that these crystal detectors utilize or constitute "imperfect electrical contacts" within the meaning of the claim and as a matter of fact.

There is nothing in the claim or the specifications of the patent to indicate that the words "imperfect electrical contact" are used otherwise than in their ordinary signification. The meaning of the words is so plain that it cannot be aided by definition. The crystal detector does not utilize an imperfect electrical contact in the detection of Hertzian waves but requires a good small contact of such a degree of perfection that it is necessary when the contact becomes imperfect to restore the perfect contact. It is argued on behalf of plaintiff that because the crystal detector has a higher resistance than the terminals between which it is interposed it constitutes an imperfect electrical contact. On this point Judge Veeder says:

"From an electrical point of view the defendant's detectors are not imperfect electrical contacts, as the term is used by Marconi, because the electrical condition is permanent from wave to wave of electrically received impulses. Moreover, the defendant's devices are rectifiers, which means that in any complete cycle or complete wave of alternating current the positive half wave passes through the device with less obstruction or greater power than the negative half wave. This rectifying action is a definite property, which is the same from wave to wave. The defendant's detectors do not operate in the same manner as the Marconi coherer."

In a detailed statement, Judge Veeder pointed out that the coherer is a make-and-break device, whereas the crystal device is not at all of that nature but one which changes the received alternating signalling oscillations into direct current, the energy received and detected being that of the transmitted energy rather than that of a local battery.

It is also contended that the patent is infringed by the transmitters which defendant used. It is argued in effect on behalf of plaintiff that the connection with the earth described in claim 3 of the Marconi patent refers to *any* connection with a secondary circuit. But plaintiff cannot have both a general claim for any connection and a specific claim [fol. 68] for a connection made in a particular and definite way. If the claim is general it would be anticipated by prior disclosures of ground connections in wireless signalling apparatus but Marconi could not have an all inclusive right to every kind of earth connection. The patent in suit describes and claims a specific arrangement of grounded antenna. It requires one end of the spark producer and one end of the coherer to be directly connected with the earth and the other end of the spark producer and the other end of the coherer to be connected with an insulated elevated conductor.

The effect of these direct electrical connections is obviously in the case of the receiver to cause all the high-frequency current induced in the antenna circuit to pass or flow directly through the coherer and in the case of the transmitter to cause all of the energy created by the spark discharge to circulate in the antenna circuit. The transmitting circuits and receiving circuits used by defendant were quite different in their arrangement and function. All included

a transformer connection between the antenna circuit and the closed circuit; the latter circuit in the transmitter included the spark producer or gap and in the receiver included the crystal detector. The transformers were of two types: viz, those with (*a*) separate primary and secondary windings; (*b*) an auto-transformer type of winding.

In all instances in which a transformer having separate primary and secondary windings was utilized there was no direct electrical connection between the ground and the antenna and the spark producer or gap in the transmitter, or between the ground and the antenna and the detector in the receiver. With this type of transformer no physical metallic connection exists. The coupling is merely inductive in its character. This arrangement is shown in the diagram set out in Finding XXII illustrating the apparatus of the Wireless Specialty Apparatus Company. In the transmitting and receiving circuits utilizing the auto-transformer type of coupling there was a direct electrical communication between the primary and secondary winding in the coupling of the closed circuit to the open circuit, but as shown in Finding XXI this is merely incidental to the construction of the auto-transformer, the true function of which is to electro-magnetically couple the open and closed circuits together, and such electrical connection is not for the purpose of connecting the receiving antenna and the ground directly to the detector so as to pass all of the high frequency currents generated in the antenna through the detector as was done by the apparatus described in the Marconi patent. In fact this connection was merely incidental and not for the purpose of connecting the antenna and the earth directly to the spark producer or gap. In other words it functioned differently than did the apparatus of the reissue patent.

We do not overlook the fact that in the cases cited by Judge Veeder no physical contact was shown to exist between the apparatus and the ground, whereas in the case before us in part of the apparatus there was such a physical contact, although it can be said that it was made in a different manner and operated differently. But this fact does not affect the primary question here.

As stated above, plaintiff's patent is on the combination. In *Loom Company* v. *Higgins*, 105 U. S. 580, it is said: "If a new combination and arrangement of known elements

[fol. 69] produce a new and beneficial result, never attained before, it is evidence of invention." This quotation may sustain plaintiff's claim that the combination was patentable but it also shows that the patent thereon was not infringed.

At this point, keeping in mind that it has already been shown that all the elements of the reissue patent are old and that none of its individual features considered separately and alone were patentable, it becomes quite clear that a new combination made by another party presenting a new arrangement, producing new and beneficial results does not infringe a former combination by using some of the elements thereof.

In conclusion we hold that the reissue patent was not infringed:

(1) Because the apparatus used by defendant included in its combination a new element, namely, the crystal detector;

(2) Because defendant's apparatus was differently arranged in that the spark gap and detector were not in the antenna circuit where they were located under plaintiff's patent;

(3) Because the changes made in the combination by defendant had a new and beneficial result.

The Lodge Patent, #609154

The findings show that the British patent to Oliver Joseph Lodge, #11575, was filed May 10, 1897, over seven months before the United States application for the same invention, the patent in suit No. 609154, was filed. The British patent, however, was not sealed until October 25, 1898, and the United States patent to Lodge was issued August 16, 1898. The actual certificate of the British patent therefore was not issued until after the American patent had been granted. By section 3 of the act of 1897, section 4887 of the Revised Statutes was amended to read as follows:

"No person otherwise entitled thereto shall be debarred from receiving a patent for his invention or discovery, nor shall any patent be declared invalid, by reason of its having been first patented or caused to be patented by the inventor or his legal representatives or assigns in a foreign country,

unless the application for said foreign patent was filed more than seven months prior to the filing of the application in this country, in which case no patent shall be granted in this country."

Under the provisions of this statute the invalidity of the patent will not be shown merely by the fact that the application for the patent in the United States was not made until more than seven months after the application for the foreign patent was filed. It must also appear that the invention was first patented in a foreign country. In the case of the Lodge patent, if we take the dates when the patents were actually issued, we find that for some reason the date of the letters patent issued in England is subsequent to that of the one issued in the United States. We do not think, however, that this fact, when we consider the English statute and the obvious intention of the provisions of the law in the United States, is determinative of the question now before us. The complete specification for the British patent was accepted August 10, 1898, and the British [fol. 70] patent was sealed October 25, 1898. Under the British law acceptance gave "like privileges and rights as if a patent for the invention had been sealed." In *Davies* v. *Townsend*, 13 R. P. C. 265, the defendant was accused of having sold goods marked with the word "patented" when no patent had been granted. The suit was dismissed because his application had been accepted and he had the same rights as if a patent had been sealed on that day.

In *Smith* v. *Goodyear Dental Vulcanite Co.*, 93 U. S. 486, 498, the Supreme Court held with respect to an English patent: "Though the provisional specification was filed March 14, 1855, the completed specification was not until the 11th of September following. It was, therefore, on the last-mentioned date that the invention was patented."

The last clause of the statement above quoted obviously has no general application, but refers merely to the case then before the Court.

In the *Smith* v. *Goodyear case, supra*, the date when the British patent was granted to Goodyear was not important, except upon the question of the priority of the invention. It did not affect the validity of the patent which Goodyear took out in the United States. The question which the court was deciding was a very different one from the one in-

volved in the case at bar in which we are required to determine what is meant by the words "first patented * * * in a foreign country" as used in the statute. In Great Britain, while the rights of a patentee date back to the time when the completed specifications are filed, his rights do not become fixed and settled until the patent is "sealed." The specifications may be sufficient and approved but if the patent is not "sealed" he receives no certificate that a patent has been granted and no rights accrue to him as a patentee. We think, therefore, that the word "patented" as used in the statute refers to the time when plaintiff's right to a patent is fixed and determined and this in Great Britain would be the date when it is "sealed." In the case at bar the Lodge patent was not sealed in Great Britain until after it had been granted in the United States. We conclude therefore that Lodge's patent taken out in the United States cannot be held invalid by reason of the subsequent issuance of the British patent on the same invention.

It is urged that there was such laches in enforcing the claim for infringement under the Lodge patent as to prevent any recovery for that reason even if the patent be held valid.

Title to the Lodge patent was acquired by plaintiff on March 19, 1912, a little less than three and a half years before it expired. Mr. Marconi admitted in his testimony that his company had previously been openly infringing the patent since the time of its grant. The evidence also shows that the loading coil which is one of the basic features of the Lodge patent had been used openly by the Navy since 1903, by the Army since 1908, and by the Stone Wireless Telegraphy Syndicate in 1902. In fact, the Stone Company openly used the induction coil in its antenna for several years, but was never notified of infringement or sued under the Lodge patent. Suit could have been brought thereon as early as 1903 against the manufacturers of the apparatus manufactured by the Stone Wireless Telegraph System and other contractors who made it for the Govern-
[fol. 71] ment. But this was all prior to the time that the plaintiff acquired the Lodge patent. About that time or shortly after it acquired the patent, as stated in Finding XII, the United States was orally notified with reference to the four patents in suit including the Lodge patent in the

winter or spring of 1912 at a White House conference at which the President and four members of the Cabinet were present and written notice of the two Marconi patents, and the Lodge patent, and their infringement was given by registered mail to both the Navy and War Departments on March 7, 1913, and March 8, 1913, respectively.

The facts recited above show clearly that prior to the time the plaintiff acquired the Lodge patent there had been such laches in asserting any rights thereunder that any person interested might well believe that the patent had been abandoned. The contention of the defendant is that the laches on the part of the owners of the Lodge patent prior to the time when plaintiff acquired the ownership thereof not only prevents a recovery for any use of the patented device prior to that time but in effect invalidates the patent and prevents any recovery for infringement thereof after notice was served upon defendant that it would be held liable for any infringement thereof. Several decisions are cited in support of this contention. All of them hold that the party to whom a patent has been transferred must bear the burden of the acts of his predecessors in ownership and where they have been guilty of laches the effect thereof carries on to the new owner. Consequently, where the apparatus alleged to infringe the Lodge patent had been purchased prior to the time when the notice was given by plaintiff to defendant, as shown above, there can be no recovery on account of such use. This rule we think will apply whether use was made of the patented device before or after the purchase of the apparatus used.

But as to apparatus purchased or any use of the patented device after notice of the plaintiff of intent to enforce its rights under the patent, we think the rule is different. None of the cases cited go so far as to hold that, after notice has been given that the owner of the patent will insist upon his rights, previous laches prevents any recovery for subsequent infringement arising from the use of apparatus made or purchased after the notice had been given. On the contrary, it was held in the case of *Simpson* v. *Newport News Shipbuilding & Dry Dock Co.*, 18 Fed. (2d) 318, 321, where the notice was given prior to manufacture and use by the defendant of the patented device, that previous laches on the part of the plaintiff with respect to other parties would not prevent a recovery. A recovery was denied only because the final conclusion was that the patent was invalid.

In the case of *Marconi* v. *National Co., supra,* which involved the same plaintiff and the same patent (Lodge patent), the plaintiff was not permitted to recover on account of use of the patented device prior to the suit but the patent was sustained and an injunction granted against further infringement. In this case the opinion does not show that the defendant received any notice with reference to the infringement prior to the time when the suit was begun. *Richardson* v. *Osborne & Co.,* 82 Fed. 95, is an extreme case. The suit was not begun until two months before the patent had expired. The opinion shows that the defendant had been using the patented device for nearly [fol. 72] fourteen years without being disturbed or molested and was carrying on a very large business with every reason to believe that the plaintiff would not make any claim under his patent. If the plaintiff had been permitted to maintain his suit, it is manifest that the defendant would have sustained a large loss upon investments made in good faith and the defense of laches was sustained. The opinion in this case cites a large number of cases bearing on the effect of laches generally. Only a few of these cases involve patents. The principles which relate to the effect of laches apply to all suits where laches in commencing a suit is shown and are not peculiar to patent cases. The rule of law which is applied is based upon the principle that it is manifestly inequitable to permit a plaintiff to recover upon an act of the defendant for which the plaintiff himself is largely to blame. In patent cases, while recovery is often denied on account of laches, the patent is not held invalid.

In the case at bar, we see nothing inequitable in holding the defendant liable where the apparatus alleged to infringe was made or purchased after the defendant was served with notice of plaintiff's claim, but where the apparatus was purchased or made prior to the service of such notice our conclusion is that there can be no liability.

Mere use of infringing apparatus after the notice was given, we think, is not sufficient to make the defendant liable. Where defendant purchased or made the apparatus before notice and had thus invested its money or gone to expense in good faith, having reason to believe that no claim would be made by plaintiff, we think the plaintiff would be estopped from complaining of the use of the apparatus after the notice.

Validity of the Lodge Patent

Before the Lodge patent was taken out it was known that with alternating currents of given frequency a circuit will carry its strongest current under a given pressure or voltage when there is a condition of resonance, or, in other words, when the natural period of the circuit corresponds with the frequency of the current. In the alternating-current circuit its natural period depends on the extent of its capacity and inductance, or self-inductance as it is sometimes called. It was also known that a helical coil of wire had principally inductance and an electric condenser had essentially capacity, and that variation in the amount of either the inductance or capacity changed the period of the circuit. The most important feature of the Lodge patent was the use of a self-inductance coil between a pair of capacity areas in the oscillating circuit of either or both a sending or receiving set for Hertzian wave telegraphy. As shown in fig. 9 of the patent drawings set out on page 15, Lodge made use of an adjustable coil whereby the extent of its self-inductance could be varied. The purpose of such a coil was to control the oscillations excited in the system and constitute the system a resonator or absorber of definite frequency or pitch, which acted cumulatively with a distant radiator of corresponding period also capable of acting cumulatively. By this method, as he stated in claim 5, "signalling may be effected between any two or more cor-[fol. 73] respondingly attuned stations without disturbing other differently attuned stations." (See claims 1, 2, and 5 of the Lodge patent as set out in Finding XXVIII.)

It is quite evident from the claims made by Lodge, as set out in Finding XXVIII and his diagrams of apparatus which accompanied the patent and which are set out on pages 14 and 15, that Lodge contemplated varying either the inductance or capacity or both in such a manner as to attain syntony or resonance and prolong the electrical oscillations excited in the system. An important feature of the apparatus for this purpose was the adjustable coil. The defendant, to show that Lodge offered no new invention when he proposed to tune the circuits in syntony, cites *Marconi* v. *National Co.*, *supra*, in which Judge Veeder said: "Tuning the two circuits of a transformer was common knowledge, and was practised by Ducretet, Braun, Lodge, Tesla, and Pupin, and was described and used by Fessen-

den prior to 1900"; and also the decision of the British court in a case where the owners of the Lodge patent brought suit for prolongation of the Lodge British patent reported in Reports of British Patent Cases, vol. 28, page 365. In this case the court considered the third, fourth, and fifth claims of the Lodge patent with reference to tuning the transmitters and receivers and said:

"With regard to tuning, in the sense of varying the natural frequency of a circuit, it had long been well known that this could be done by varying either the induction or the capacity, or both the capacity and the induction of the circuit. For tuning his syntonic jars, Lodge had provided means for varying the induction. Under these circumstances, again, I cannot think that tuning by means of induction coils switched in or out as desired, or by means of adjustable induction coils can be considered in itself a great invention."

And the court refused to grant extension of these claims. Apparently the British judge considered that everyone skilled in the art would know that the effect of an induction coil could be varied by varying the number of separate turns of wire used and for this reason it was no invention to use an adjustable coil in the circuit for the purpose of tuning it. All this may be conceded and yet we think it does not render the Lodge patent invalid and ineffective as to infringement. Lodge's invention, as we view it, consisted of a new combination in which features which may be said to be old when considered apart and alone, were so associated as to produce new and valuable effects.

We do not think it is necessary to consider in detail the patents granted to Pupin, Hutin, Tesla, and Stone, referred to in the findings, although they were granted prior to the time the patent to Lodge was issued. These patents show that the laws of closed resonant circuits in general were known prior to the Lodge invention, but there is nothing in these patents which shows knowledge of the desirability of tuning an ~~open~~ oscillating circuit for Hertzian-wave signalling. Lodge took features that were old and combined them in such a way as to produce new and useful results which had never been accomplished before. While the laws [fol. 74] regarding the relationship of capacity and inductance to achieve the tuning of an alternating current cir-

cuit were known prior to Lodge's invention, no satisfactory evidence has been produced to show that the elevated wire of a Hertzian-wave transmitter or receiver and the ground connection were known to constitute an electric condenser in the open oscillating circuit prior to the Lodge invention. Lodge appears to have been the first to recognize that the elevated wire and ground connection constituted a condenser and was the first to realize the desirability of applying the known laws of resonance for closed circuits to a Marconi open oscillating circuit. The Marconi patent #586193 (the original patent which was reissued as the first patent in suit) contemplated the use of plates of such length that the receiver would be "electrically tuned with the electric oscillations transmitted", but there is no evidence that this method would work satisfactorily, and Lodge asserted at the time his patent was reconsidered that the method recited in the Marconi patent would not work at all. In any event, the evidence shows that if this method ever was put in use it was entirely superseded by the method which Lodge used. Lodge's invention increased the range for signalling with Hertz waves and it went into wide and almost universal use, superseding other methods.

We think on the whole that while none of the features of the Lodge patent may be said to be entirely new, Lodge had taken these features and in a new combination had so used the most useful function of each as to obtain better results than had ever before been reached. We conclude, therefore, that his patent was not void for want of novelty.

Tesla's patent #645576, the application for which was filed before that of Lodge, although the patent itself was issued later, is mentioned as anticipating the features of the Lodge patent. But the system of Lodge made use of a different combination from anything disclosed by Tesla and was operated differently.

It is said that the decision in *Marconi* v. *National Co.*, *supra*, which sustained the Lodge patent is based on erroneous assumptions, but we do not need to agree with all that Judge Veeder said in order to concur with his conclusion, which we think was well founded.

In the case of *Marconi* v. *Kilbourne & Clark Mfg. Co.*, 239 Fed. 328, the court treated the validity of the Lodge patent as being settled and held it was infringed. This case is chiefly useful as showing the improvements and special

features of the combination which Lodge used and the manner in which it operated.

The Lodge patent was also held valid in the case of *Marconi* v. *DeForest Radio Tel. & Tel. Co.*, 225 Fed. 65, affirmed 225 Fed. 373. If we are correct in holding the Lodge patent valid, then the defendant has infringed this patent by the use of the apparatus of the Wireless Specialty Company and other apparatus as more particularly set out in Finding XXXIV, and the defendant would be liable for such infringement unless it purchased or acquired the apparatus prior to the time it received notice from the plaintiff that it proposed to enforce its rights under the Lodge patent.

The Marconi Tuning Patent #763,772

[fol. 75] This patent is sometimes referred to as the "four circuit tuning patent" but is commonly called the Marconi tuning patent. The patent relates to means for providing a stronger transmitted signal in wireless telegraphy and means for rendering the receiver more selective than had resulted in the previous practice. Both the receiver and the transmitter had an open antenna circuit and a closed oscillation circuit which were tuned to the same frequency or time periods, and all four also synchronized. This resulted in having a somewhat stronger signal radiated by the transmitter and a more sensitive reception by the receiver. In this respect it was successful and went into wide use in the United States and elsewhere. It is claimed that by means of this invention there was a substantial increase in the distance of reliable radio transmission and reception and also an increase in the selectivity of radio apparatus which in turn made possible an increase in the number of transmitting stations which could be used at the same time without interfering with each other. Apparatus embodying the invention of #763,772 was employed in the first transatlantic radio signalling.

A number of claims under this patent are involved in the suit. These claims are set out in Finding XL which also contains an explanation of some of the more important claims in connection with the diagram contained in Finding XXXVIII. Some of these claims are directed to the transmitter, some to the receiver, and some to a communication system involving both the transmitter and the re-

ceiver. But so far as the validity of the patent is concerned it will not be necessary to consider these claims separately.

Two defenses are made against this patent, the first being that the patent is invalid and the second that there has been no infringement in any event. The alleged invalidity of the patent is based upon prior patents and disclosures.

Marconi had a great deal of difficulty in obtaining this patent. The original application for the patent was filed November 10, 1900. Before it was reached for action and on July 1, 1901, the entire original specification and all of the claims were canceled and a new specification and set of claims were substituted. The examiners who first considered the case rejected the application. During more than three years afterwards new applications and petitions for revival were filed and rejected by reason of the prior art set forth in the Braun British patent; Lodge #609154; Marconi #627650; and Tesla #645576. During the prosecution in the Patent Office of this patent, the examiner rejected all claims made therein except 15 basing his rejection on the Tesla patent #649621 and particularly said in his letter that claims 4, 13, 14, and 16, which specify a variable inductance and means for adjusting the inductance, were not patentable over Tesla because Lodge had shown that this was old, and the examiner also stated that claims 3 and 5, which specify an adjustable condenser, were not patentable over Tesla.

After this holding of the examiner, nothing was done by Marconi until October 6, 1903, when a petition was filed [fol. 76] asking that the application be revived. The examiner recommended that the petition be denied, citing as additional prior art a paper by Pupin and the Stone patent #714756 which had been issued on December 2, 1902, and on December 3, 1903, the Commissioner denied the petition to revive. At the time of filing the petition for revival on October 6, 1903, the applicant presented an amendment containing the present claims 1, 2, 3, 6, 8, 9, 10, 13, 14, 15, 16, 17, 18, and 20. Elaborate arguments and affidavits were submitted and the Commissioner submitted a long report in effect denying the application. Another petition for revival was presented on February 19, 1904, and granted by the Commissioner. The case was acted upon by a new examiner and all the claims formerly re-

jected by the other examiner except four were immediately allowed in accordance with a brief letter in which it was stated, among other things, that all claims which included the element of variable inductance were considered allowable over the Stone patent and that claims 4, 5, 6, and 7 would be allowed if amended by inserting the words "a variable inductance and" after the word "including" in line 3 of each claim.

Patent #763772 has several times been before the courts. In the case of *Marconi* v. *National Co.*, *supra*, this patent with other patents was in issue and was held valid and infringed as to claims 1-3, 6, 8, 10-13, 16-20. The device used by the defendant in that case had loose coupling, signifying a plain open gap. It is not clear whether the court considered the rotary and quenched gap apparatus involved in the instant case to be also infringements. Preliminary injunctions were granted in the case of *Atlantic Communication Co.* (not reported) and the *DeForest Radio Tel. & Tel. Co.*, 225 Fed. 65. In the case of *Marconi Wireless Telegraph Co.* v. *Kilbourne & Clark Mfg. Co.*, 239 Fed. 328, the validity of the patent was not determined but it was held that quenched gap transmitters did not infringe. In another case with the same plaintiff against the *United Wireless Telegraph Co.* in the Southern District of New York, claims 1 to 20 were held valid and infringed but the case has not been reported.

The British patent #7777, of 1900, corresponding to the patent in suit, was sustained as was also the corresponding French patent.

It will not be necessary to consider the claims of the patent in detail as the matter in controversy between the parties is confined to a narrow issue.

The fundamental principle of the patent is embodied in an apparatus utilizing a transmitting station of two circuits, an open antenna circuit and a closed oscillation circuit, which are coupled together and both of which are tuned to the same or substantially the same frequency or wave length; and the use of a receiving station of two similar circuits which are likewise tuned to the same or substantially the same frequency or wave length with each other and the transmitter.

All of the wireless sets of defendant made use of apparatus constructed in accordance with the principle which

formed the basis of the patent. We will, therefore, next [fol. 77] consider the question of the validity of the patent. In so doing it is important to observe that when used with reference to electrical circuits the words "tune" and "synchronize" have the same meaning and that when circuits are "tuned" or "synchronized" with each other they are said to be in "resonance."

Finding XLIII shows that the examiner who at first refused to allow the patent based his rejection on the patents of Tesla and of Lodge. Tesla obtained two patents prior to the Marconi tuning patent—#645576 and #649621. In these patents Tesla made use of an open antenna circuit and a closed oscillation circuit in both the transmitter and receiver, all of which were tuned together or synchronized. Tesla did not refer to the matter of tuning by adjustable inductance but one of the examiners who rejected Marconi's application stated that it was fair to assume Tesla intended to use either that method or a condenser, or both, to accomplish this purpose. This was necessarily so for these methods were known at the time and it could be accomplished in no other manner.

Judge Veeder in the *National Electric Sig. Co. case, supra*, says that Tesla's patent #454622 of 1891 contains no suggestion of tuning and seems to lay great stress upon that fact. This patent is not in evidence in the instant case and is not before us. Tesla's patent #645576 of date March 20, 1900, the application for which was filed before the Lodge patent, was upon a four circuit system and referred to the synchronization of the circuits no less than six times therein. In one place he says "the primary and secondary circuits in the transmitting apparatus being carefully synchronized, * * *"; and that "the results were particularly satisfactory when the primary coil or system *A′* with its secondary *C′*, was carefully adjusted, so as to vibrate in synchronism with the transmitting coil or system *AC*."

Finding LXII includes a diagram of Tesla's system as set out in his patent. The specifications show that Tesla had the two circuits in the transmitting apparatus synchronized or tuned together and the two coils in the receiving apparatus tuned together and made to "vibrate in synchronism with the transmitting coil." Further on Tesla specifies "the feature of a transmitting and receiving coil

or conductor, both connected to the ground and to an elevated terminal and adjusted so as to vibrate in synchronism."

In three other places Tesla refers to the circuits of his system being "synchronized." Just what method he proposed to use for synchronizing the circuits is not stated, but Lodge had shown how it could be done by the system of adjustable inductance and as we have specially found (see Finding LXII), anyone skilled in the art was capable of applying the Lodge method of tuning to the Tesla system. The last Patent Office examiner in his letter of March 31, 1904, giving reasons why the patent should be granted, after referring to the method used by Stone to synchronize the circuits, said:

"Applicant discloses another means whereby the same result may be effected, viz. by including a 'variable inductance' in the elevated conductor. All claims which in- [fol. 78] clude this element are considered allowable over the Stone patent.

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"Claims 4, 5, 6, and 7 will be allowed if amended by inserting the words *a variable inductance and* after the word 'including' in line 3 of each claim."

From this statement it is evident that the only basis the examiner could find for allowing the claims was the feature of variable inductance in a specific location as a means of bringing all the circuits into resonance. The examiner does not seem to have given very careful consideration to the matter at hand for he overlooked the fact that claims 10 and 12 as well as claims 4, 5, 6, and 7 contain no reference to variable inductance. He should have known that Lodge had shown and patented the use of a variable self-inductance coil to attain a condition of resonance or syntony between circuits, and it cannot be contended that the feature of variable inductance was new in itself. Marconi used it for the purpose of doing what Tesla had done without specifying the method. After Tesla had filed his application in #645,576, Lodge showed how it could be applied and advantageously used in the application for his (Lodge's) patent. Tesla filed his application for #645,576 in September 1897. Lodge filed his application February 1, 1898. Tesla therefore did not have the knowledge of the manner in which

Lodge made use of the principle of tuning by adjustable inductance, and as Lodge's patent was issued in 1898 and Tesla's #645,576 not granted until 1900, it may be that neither knew of the work of the other. But after these patents were issued it was only necessary to put them together to have the Marconi system. We think the examiners who first rejected the Marconi application were right and that the last examiner who granted the patent was wrong.

Judge Veeder in the *Nat. Electric Sig. Co. case, supra,* calls attention to a new theory propounded by Tesla in his divisional patent #649,621 and seems to consider that because Tesla's theory was different from that of Marconi, Tesla's system does not anticipate that of Marconi. But we are not here concerned with theories. What we have to deal with are Tesla's specifications, the apparatus which he described, the manner in which he proposed to use it, and the effects which it would accomplish. He may be and probably was entirely wrong as to some of his theories but there is no doubt about these essential matters. Claim 10 of the Marconi patent recites:

"A system of wireless telegraphy, in which the transmitting-station and the receiving-station each contains an oscillation transformer, one circuit of which is an open circuit and the other a closed circuit, the two circuits at each station being in electrical resonance with each other and in electrical resonance with the circuits at the other station, substantially as described."

The specifications of this claim are repeated in a different form and with different words in claim 3 of Tesla's #649621. If anything is lacking it is supplied elsewhere in other claims made in Tesla's patent. In this connection it should be said [fol. 79] that some importance has been attached to the fact that Marconi used a persistent oscillator, but Tesla also describes a persistent oscillator. Claim 10 is sometimes referred to as the "broad claim" of the Marconi patent. It is quite plain that it was anticipated by Tesla whatever his theories may have been, and so far as the other claims of the Marconi tuning patent are concerned we think we have already shown good reasons why they should be rejected.

It is sometimes said that Tesla's purpose was only to transmit electrical energy, but the electrical waves trans-

mitted by any wireless system are merely one form of electrical energy. Moreover, the specification of Tesla's patent recited that the method of energy transmission would be useful when it was desired to transmit intelligible messages great distances. In view of this statement it would be within the knowledge of those skilled in the art to interrupt the continuous generation of high-frequency energy in the transmitting system by a telegraph key and substitute for the current receiving instrumentalities disclosed in connection with the receiving system a radio signal detector device.

If we are correct in what has been stated above, the Marconi tuning patent is invalid, but it should be noted that other defenses are strongly urged by the defendant based upon the Stone patent and certain disclosures made in letters written by Stone. As stated above, Stone's application was filed prior to that of Marconi and his patent was also granted before that of Marconi, although it was not allowed until after an amendment to the specifications had been made and this amendment was filed after Marconi's application.

Stone, in the original application for his patent, discloses a four-circuit system in which the transmitting and receiving open circuits are each associated with a closed circuit and the two closed circuits are tuned in resonance with each other. As we have before stated, all of the different features of the Marconi patent considered separately and individually were old and Marconi could obtain a valid patent only by proposing a new combination of these features which produced new results and this combination also must not be one which would naturally suggest itself to one skilled in the art. Here again in connection with Stone's patent we conclude that Marconi's patent does not come within this rule. Tesla had shown the advantage of all four circuits being syntonized; Lodge had taken the two-circuit system and tuned or synchronized the open circuits in the same manner afterwards used by Marconi; Stone had disclosed in his original application a four-circuit system in which the closed circuits were tuned together. A consideration of these three systems would naturally suggest to one skilled in the art the tuning of all four circuits together by the use of the adjustable self-inductance method in the manner proposed by Lodge, and Stone put this suggestion into practice when he filed the amendment to his specifications. Marconi used the suggestion earlier in the application for his

patent, but under the circumstances as we think neither Stone nor Marconi was entitled to credit for it.

A quite unusual situation is presented by the conflicting patents of Marconi and Stone. As before stated, Marconi applied for the patent which subsequently became #763772 November 10, 1900. Stone filed the application for his patent on February 8, 1900, and on April 8, 1902, Stone filed an amendment to his specifications which proposed a four- [fol. 80] circuit system with all the circuits synchronized. His patent was allowed on December 2, 1902, while the Marconi patent #763772 was not granted until June 28, 1904. In 1899, Stone wrote two letters to a friend of his by the name of Baker in which he disclosed a four-circuit system with all the circuits synchronized, but, as we have seen, he did not actually put such a system in practice until he filed the amendment to his specifications on April 8, 1902.

The Stone patents and disclosures were not before the British court, or Judge Veeder in the *National Electric Sig. Co. case, supra*, but were before the court in the *Kilbourne & Clark Co. case, supra*, decided by Judge Neterer. In the argument for plaintiff it is said: "Judge Neterer overruled this defense." The opinion of Judge Neterer shows that he considered the Stone letters and that they disclosed a four-tuned circuit system. It was unnecessary for him to pass on the validity of the Marconi tuning patent and he did not do so for the reason that he found there was no infringement. If any inference is to be drawn from his opinion it is that it was proper to take into consideration the Stone letters.

It is contended with much force on behalf of the defendant that the letters written by Stone which are referred to in Finding LV anticipated the Marconi patent even if it otherwise be held to be valid, but it is not necessary that we should decide whether a private letter such as Stone wrote to his friend would constitute a disclosure which would affect the Marconi patent, for without considering these letters we think patent #763772 was invalid for the reasons stated above, except as to claim 16, which relates to a matter not covered by the other claims.

Some argument is made in favor of the Marconi patent, based upon the fact that Marconi made use of a persistent oscillator, but this was used in the earlier Marconi patent #586,193. The use of the persistent oscillator is, we think, important only when the question of infringement by the use of the quenched-gap apparatus is considered.

The alleged infringing apparatus may be classified in three groups: (*a*) The plain open-gap apparatus; (*b*) that having a rotary gap; (*c*) the larger group using a quenched gap.

If we are correct in holding that the Marconi patent #763,772 is invalid, there would, of course, be no infringement in any event, but if it should be held that the patent was valid then it becomes necessary to consider whether any or all of the apparatus used by defendant infringed thereon. We think it clear that the plain open-gap apparatus would be an infringement if the patent was valid, and we are likewise of the opinion that this would be true as to the apparatus using the rotary gap which, as we think, was merely a variation of the plain open gap and apparently used for the purpose of cooling the terminals used in making the gap across which the spark passed. In this connection it should be observed that Marconi did not confine his patent to any particular kind of spark producer and evidently intended that any known kind might be used. The rotary gap might in some respects have been superior to the plain open gap, but it did not function in any different manner.

The form of the device which constituted the quenched-gap spark producer and its action as such are set forth in [fol. 81] Finding XLVIII. The evidence is conflicting as to whether in its effect upon other parts of the apparatus it functioned differently from the plain open gap. In any event, it would seem that it was only another device for a spark producer and that Marconi in an earlier patent had shown a somewhat similar contrivance. It also appears that when it was used it was necessary to follow the same method of tuning as before. On the other hand, this device apparently was more efficient than the plain open gap for in a comparatively short time it largely displaced the latter system.

In view of the fact that we have found the Marconi patent #763,772 invalid except as to claim 16, we do not find it necessary to determine whether apparatus making use of the quenched gap constituted an infringement.

Claim 16 is set out in Finding XL. We shall not consider it at length as we have no doubts with reference to its validity. It relates to a different subject matter from any of the other claims and is directed to a combination of elements which is new and useful.

The claim refers to a receiving station in which the principal features are the combination of an oscillation transformer with an open circuit connected with one coil of the transformer and including an oscillation-receiving conductor at one end and capacity at the other end, with an adjustable condenser in a shunt connected with the open circuit and around the transformer coil, a wave-responsive device electrically connected with the other coil of the oscillation transformer, and means for adjusting the two transformer circuits in electrical resonance with each other. These features are shown in the diagram of the receiving station found in fig. 2 of Finding XXXVIII, where the means for adjusting the two transformer circuits in electrical resonance with each other are indicated. It may be said, however, that the purpose of the adjustable condenser in shunt with the primary winding of the transformer in the open circuit of the receiver is not described in this patent; but the specifications of the patent include tables showing the preferred adjustments in connection with the induction coil as numbered therein, and we think these tables would indicate to one skilled in the art that the use of the condenser connected in shunt with the primary winding of the transformer of the receiver was for the purpose of enabling the electrical periodicity or tuning of the open circuit of the receiver to be altered and adjusted. So far as disclosed by the evidence, prior to the Marconi patent, no such apparatus had ever been used or devised. Being new, if it was useful, it was patentable. Its usefulness, we think, is shown by the fact that the receiving apparatus of the Kilbourne & Clark Company and that made by the Telefunken Company used by the Government embodied this device. Claim 16, therefore, is valid and was infringed.

The Fleming Patent, #803684

Granted November 7, 1904

This patent is entitled an "Instrument For Converting Alternating Electric Currents Into Continuous Currents", and the nature of the invention patented is well described in the patent itself (page 1, line 11) as follows:

[fol. 32] "This invention relates to certain new and useful devices for converting alternating electric currents, and especially high-frequency alternating electric currents or

electric oscillations, into continuous electric currents for the purpose of making them detectable by and measurable with ordinary direct-current instruments, such as a 'mirror-galvanometer' of the usual type or any ordinary direct-current ammeter."

Fleming's patent was granted during a period when the development of electric communications without connecting wires was extremely active. Out of the work of electrical scientists during this period grew some of the most marvelous discoveries of the properties of electricity, and great progress was made in the art of reproducing the human voice and musical tones by means of wireless apparatus in the form of what we now call radio communications. Fleming's patent in some respects was new but the defendant contends that it was new only in the use of a discovery that had been made long before Fleming applied for his patent. The apparatus used by Fleming is not very complicated. A detailed description of it with drawings is found in Finding LXIV, but we think it will be easier to understand its fundamental principles if we go back to a prior patent.

Edison was granted patent #307,031 on October 21, 1884. In Edison's apparatus he made use of an ordinary incandescent lamp which, as everyone knows, consists of a glass vacuum tube containing a filament through which an electric current is passed bringing it to a very high degree of heat. Fig. 4 of Finding LXX shows the tube marked *A* and within the loop made by the filament a plate marked *b* which is connected with a wire which passes down and out of the tube and forms another circuit (not shown in the figure) by being connected with the lamp circuit. After Edison's patent came out scientists experimenting with his tube observed that there was a unidirectional current flow in the vacuous space between the heated electrode of the lamp filament and the plate electrode, and that if an alternating current were applied to a circuit, including the plate and filament, rectification would take place and the resultant current flow would be unidirectional. This change from an alternating current to a direct current flowing only in one way has been referred to as rectifying the current and the apparatus producing this result has been termed a rectifier. Why it passed only in one direction has never been very satisfactorily explained but the fact that it

did so pass attracted the attention of scientists the world over. Fleming himself disclosed this fact in a lecture before the Royal Society in 1890. Clark Howell in a paper read before a meeting of the American Institute of Electrical Engineers in 1897 described and illustrated the "Edison effect" and mentioned the fact that if an alternating current is used to render the filament incandescent the additional current thus produced is unidirectional, and at the same meeting Dr. Kennelly said that so far as he knew this paper pointed out for the first time that an alternating current passing through an incandescent lamp giving the "Edison effect" is capable of producing in a branch circuit through a third wire in a lamp continuous or at least unidirectional currents. These proceedings were published to the world.

[fol. 83] Edison did not mention this feature in his patent and probably was not aware of it at the time he took it out, but if an alternating current was impressed upon the hot and cold electrodes of his apparatus it would function so as to rectify the current and change it from one that was alternating to one that was continuous in the additional closed circuit.

The descriptive matter taken from the Fleming patent as originally filed and set out above shows that one of its principal features is the device for converting alternating currents into direct currents whereby his apparatus acted as a rectifier. The apparatus of the Fleming patent used for rectifying the current is shown by fig. 1 in Finding LXIV, and if we examine it with respect to the vacuum tube shown therein with its heated electrode (the filament of the lamp) and its cold electrode connected with an outer closed circuit, we find that it is substantially the same as the corresponding part in the apparatus of Edison. Edison used for his cold electrode a plate placed within the filament loop while Fleming used for his cold electrode a cylinder outside of the filament loop, but this is an immaterial variation.

It is contended on behalf of defendant that the Fleming patent involves nothing more at most than a new use which is not patentable. There seems to be much force in this contention. Fleming made no substantial change in the structure of the Edison vacuum tube with its hot and cold electrodes. His first claim as originally made when taken in connection with his specifications is merely a restatement

in different words of claim 5 of the Edison patent. It is true Fleming does not refer in claim 1 to an incandescent electric lamp as Edison does, but his explanations and specifications show he intended that an incandescent lamp should be used, also that there should be two circuits and that the terminals and connections thereof should be substantially the same as those specified in the Edison patent. In the use of the respective patents, however, there was an important difference. Edison believed that the current flow through his tube was proportionate to the degree of incandescence or candle power of the filament and connected his tube in circuit with a galvanometer or relay for indicating or controlling conditions in the filament circuit. While his apparatus was capable of rectifying an alternating current he did not make use of an alternating current. On the other hand, Fleming used an alternating current which was rectified by the Edison tube and he also made use of the rectified current in connection with additional apparatus in such a way that it operated a detector in transmitting wireless messages. In this respect his apparatus was new and useful.

As a general rule a patent cannot be based upon a new use of an old device but to this rule there are exceptions. Judge Mayer in *Marconi Wireless Tel. Co. v. DeForest Radio T. & T. Co.*, 236 Fed. 942 (affirmed 243 Fed. 560), held in substance that the use which Fleming made of the rectified current and the manner in which he applied it constituted invention. He accordingly upheld the Fleming patent and his decision was sustained by the Court of Appeals. We need not, however, pass upon the question of whether the Fleming patent merely sets forth a new use of an old device as there is another and more decisive objection to its validity.

[fol. 84] It must be conceded that the original application for the Fleming patent contained specifications of inventions that were not new, and upon which the applicant was not entitled to a patent. Making a claim known to be void ordinarily vitiates the entire patent. The statutes, however, provide that under certain conditions the invalidity may be avoided by a disclaimer. In the case of *Ensten v. Simon, Ascher & Co.*, 282 U. S. 445, 452, the Supreme Court said with reference to these statutes:

"Construed together they 'enact that where a patentee claims materially more than that which he was the first

to invent, his patent is void, unless he has preserved the right to disclaim the surplus; and that he may fail to preserve that right, by unreasonable neglect or delay to enter a disclaimer in the Patent Office.' Walker on Patents, 6th ed., Sec. 254."

We have already shown that the patent recited that the invention related to new devices for converting alternating electric currents into continuous electric currents, and Fleming stated further in his patent:

"I have discovered that if two conductors are enclosed in a vessel in which a good vacuum is made, one being heated to a high temperature, the space between the hot and cold conductors possesses a unilateral electric conductivity, and negative electricity can pass from the hot conductor to the cold conductor but not in the reverse direction."

But this was not a new invention. As stated above, Fleming himself some fifteen years before (1890), in a lecture, showed that the current flowed only in one direction when an alternating current was used in connection with the lamp of an Edison apparatus, and discussed the flow of current from the hot negative terminal of the lamp to the cold electrode of the plate, observing that negative electricity flowed from the plate into an additional circuit connected with the lamp. In 1897 similar statements made by Howell and Kennelly were published. In stating this feature in his patent specifications as new and patentable, Fleming must have known that he was making a claim that could not be sustained. There could have been no inadvertence in making this statement, and this matter alone would seem to be sufficient to render the Fleming patent invalid. True, he entered a disclaimer later, but the statutes which give relief where invention has been wrongfully claimed do so only on the condition that the inventor has not unreasonably neglected or delayed to enter the disclaimer. In the case at bar the disclaimer was not entered until eleven years after the patent had been taken out and long after other inventors had discovered other and different methods of making use of the Edison device without claiming to have invented it. We think that if ever there was a case of unreasonable delay in making the disclaimer it is presented in what is now before us and that the Fleming patent must be held invalid for that reason.

The defendant also raises the question as to whether any proper part of the patent was disclaimed, as seemed to be required in *Corn Products Refining Co.* v. *Penick & Ford*, 63 Fed. (2d) 26, and also in *Grasselli Chemical Co.* v. *National Aniline Co.*, 26 Fed. (2d) 305, but we need not determine this question as we think the patent is void in any event for failure to make disclaimer within a reasonable time.

[fol. 85] Even if the Fleming patent be held valid, it is still contended on behalf of defendant that there was in fact no infringement. The determination of this issue makes it necessary to examine more in detail the claims and specifications of the patent and the apparatus described therein.

The invention of the Fleming patent #803684 relates to a rectifier that is suitable for use as a part of a detector with very high frequencies encountered in radio signalling to permit the use of an ordinary direct-current galvanometer to indicate the presence of the signals. The diagram figures in Finding LXIV reproduce the drawings of the Fleming patent, and it will be necessary to turn to this finding to understand the drawings and the description thereof as given in the finding. This description will not be repeated here. In general, however, it may be said that the Fleming device made use of a receiver consisting in part of a vacuum bulb within which was an aluminum cylinder suspended by platinum wires from the glass bulb. Within the cylinder was a carbon filament supplied with an electric current somewhat in the same manner as in an incandescent lamp, with the result that the filament is heated to a very high temperature and the current flows or was intended to flow only in one direction between the filament and the cold electrode. The radio-frequency impulses received in the antenna are induced in the closed circuit of a transformer and rectified by the vacuum tube, with the result that half of the radio-frequency waves are lost and half pass through the vacuum tube and are effective to actuate a direct-current galvanometer. Fig. 1 of the diagrams set out in Finding LXIV shows what is called the Fleming valve because it cuts off part of the current. As this valve tends to reduce the current flow, a method is shown in fig. 2 of reducing the loss of current, and fig. 3 shows how a number of these so-called "one-way valves" may be used to increase the possible current flow.

The claims in suit under the Fleming patent are numbered 1 and 37, and are set out in Finding LXV.

On November 17, 1915, the assignee, plaintiff herein, filed a disclaimer limiting the application of certain claims including claim 1, except when used in connection with high-frequency alternating electric currents or electric oscillations, and also eliminating words which showed that the apparatus described in the patent was intended to produce low-frequency currents or to make use thereof. The word "detector" as used in Fleming's specification plainly referred to a device adapted to make feeble high-frequency impulses measurable with an ordinary direct-current mirror-galvanometer, or, in other words, the term "detector" includes both the rectifier tube and the direct-current indicator of the rectified current. The term as used in the Fleming patent, however, did not include all apparatus associated with the detector tube, and did not include any amplifying tube or tubes.

The so-called Fleming valve, as shown in the description, had only two electrodes, and did not go into any extended commercial use, only about 700 Fleming valves having been shipped by plaintiff to anyone between 1910 and 1915. While in some respects an improvement on the crystal detectors, it did not entirely displace them. There is no evidence that the United States used any sets with two electrode tubes. Instead it used the three-electrode [fol. 86] which were much superior. The Navy used what is known as the DeForest audion which had a three-electrode tube, and will be described later on to show the difference between apparatus using the two-electrode tubes, and those using the three-electrode tubes.

In *Marconi* v. *DeForest, supra,* claims 1 and 37 were held valid and infringed by an audion detector having three electrodes. In another case with the same title, 261 Fed. 393, the decree rendered in the former suit was extended and Judge Mayer held the two-electrode tube to possess the same inherent ability to generate radio waves that is possessed by the three-electrode audion, and in effect that although Fleming did not know what could be accomplished with a three-electrode tube, and did not contemplate using it, he was entitled to the benefits of the device. With this conclusion we are unable to agree for many reasons. The basis of our conclusion is what we consider to be the fundamental difference in the manner in which the two-electrode tube and the three-electrode tube function.

The three-electrode tube was invented by DeForest in 1906 and patented by him in 1908. It is so called because it interposed between the heated electrode of the filament and the cold electrode of the plate or cylinder used by Fleming a third electrode in the form of a spiral of wire called the "grid", which was connected with the closed input circuit. To bring out clearly the distinction between the two patents, it will be necessary to consider just what features were covered by the Fleming patent after the disclaimer had been filed, what effects were accomplished by it, and what results attained as compared with the three-electrode apparatus used by the Government.

The Fleming patent did not include the discovery that an alternating current could be rectified by the use of what we might call the Edison tube so that only a direct current would pass through the outside circuit, nor could his patent include the discovery that the negative electrons emitted by the heated filament were of very small mass, or that the electron stream could be controlled by the potential of the cold electrode which occurs in rectifying an alternating current. In general, it may be said that the Fleming patent did not include the discovery that the Edison two-electrode valve was a suitable rectifier to change the alternating current into a direct current, nor did it include all uses for the electron emissions from the heated electrode.

Claim 1 of the Fleming patent recites:

"1. The combination of a vacuous vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, and a circuit outside the vessel connecting the two conductors."

These features which form the foundation of the Fleming patent are each and all, as we have shown above, old in the sense that they were well known to the prior art and the patent would therefore be invalid if it were not for the disclaimer which puts these features to a new use which is made more definite by claim 37 and the disclaimer. Claim 37 applies the apparatus to "electrical oscillations of high frequency" and as a detector uses the combination stated in claim 1. The disclaimer disclaimed the combination of elements in the claims "except as the same are used in connection with high-frequency alternating electric currents or electric oscillations of the order employed in Hertzian

[fol. 87] wave transmission", and also omitted the words referring to low-frequency currents appearing elsewhere in the patent application, thereby showing plainly that it was not intended the patent should apply to electric oscillations or currents of low frequency.

The invention described in the patent was broad enough to show to one skilled in the art the desirability of using the Edison two-electrode vacuum tube as a rectifier for radio frequencies of high oscillations. By the term "detector" Fleming's specification meant to one skilled in the art a device adapted to make feeble high-frequency impulses measurable with an ordinary direct-current mirror-galvanometer, and the term "detector" includes both the rectifier tube and the direct current indicator of the rectified current, but not any amplifying tube or tubes which were not mentioned in the Fleming patent and not discovered until after it had been taken out. Apparently Fleming had not thought of their use in connection with the apparatus described in his patent.

The defect in the Fleming apparatus arose from the fact that instead of amplifying the flow of the current (alternating current so rectified as to become direct current) it was reduced. It was sought to overcome this reduction by using a number of the one-way valves as shown by fig. 3 of the patent, while the three-electrode tube used by the Government tended to amplify the current and for this reason was much superior to anything that could be effected by the Fleming apparatus. The evidence shows that in the trial before Judge Mayer the two-electrode tube was made to amplify by the ionization of the residual gas in the tube, but there is nothing in the patent to indicate that anything of this kind was contemplated nor is there any satisfactory evidence to show that a Fleming valve was ever commercially operated in this manner by anyone. On the other hand, the evidence tends to show that this method was so unstable and uncertain it could not be used commercially.

The evidence also shows that the two-electrode tube can be made to amplify by means of a field outside the tube controlling the electron flow in a specially shaped tube. The effect obtained was similar to the control exerted by the grid of the three-electrode tube, but there is nothing inherent in the Fleming valve nor in the patent descriptions and specifications that would suggest the use of such a tube. On the other hand, De Forest discovered that the

three-electrode tube had a different effect upon the current from that produced when a two-electrode tube was used, and most important of all, that when the three-electrode tube was used the effects of the current flowing in the input circuit could be greatly amplified. The invention of the three-electrode tube and its amplifying use had a greater effect on the art than the two-electrode tube and the apparatus as described in the Fleming patent. The Fleming tube did not possess any inherent ability to generate radio waves and it could not be made to amplify them, except by circuit connections never appreciated by the inventor of the patent in suit. The defendant never operated any two-electrode tubes by any of the methods above mentioned.

The alleged infringements are all based on the use or sales of three-electrode tubes and apparatus for using them. The general construction of the apparatus for using three-electrode tubes is shown in the diagram of the De Forest audion set out in finding LXXV. This apparatus was used by the Navy and contains the principal and most important features of the apparatus which made use of the [fol. 88] three-electrode tube. The same finding describes at length in connection with the diagram the special features of the apparatus and its purpose. This descriptive matter will not be repeated except to show the difference between the De Forest invention and that of the Fleming patent. One of the marked differences was that the Fleming patent contemplated detection by rectification of the full radio or high-frequency oscillations impressed upon an indicator adapted to register the strength of the rectified one-way pulsating current, while the three-electrode tube in the diagram set out in finding LXXV and marked "Exhibit 83" detects by substantially suppressing the high-frequency oscillations and amplifying principally the low or audio-frequency oscillations. In this connection it will be remembered that the plaintiff filed a disclaimer with relation to the patent now under consideration which in effect withdrew its claims except as they related to high-frequency currents or oscillations. In contrast, the De Forest audion made use of the low-frequency oscillations. Part of the reason for this was because the audion was intended to be used in connection with a telephone, and the low-frequency oscillations are better adapted for use with that instrument.

The De Forest audion introduces the new feature of the so-called "grid" (marked "G" in the diagram), illustrated in Finding LXXV, which makes a third conductor or electrode in the outer tube marked "T" which contains three conductors adjacent to but not touching each oth and means for heating one of the conductors.

The purpose of the apparatus making use of the third electrode was to effect a control of the electron stream and to furnish a means of amplifying the radio signals. This third electrode is connected to an input circuit and is separate from the output circuit, which contains an additional source of energy, with the result that a radio signal impressed on the input (grid) circuit is reproduced in amplified form in the output circuit; also the grid circuit constitu s a means for impressing upon the plate circuit principally the audio (low) oscillations received and not the radio or high-frequency oscillations contemplated by claim 37 of the patent. These high-frequency oscillations are substantially suppressed by the grid condenser of the three-electrode tube, while the Fleming patent, as before shown, contemplated detection by rectification of the radio or high-frequency oscillations as impressed upon an indicator. The great advantage of the apparatus used by the defendant was that it could be so used as to amplify almost indefinitely the received signal and thus enable communications to be made over far longer distances and with much greater accuracy than could be accomplished when the two-electrode apparatus was used with its reducing effect.

Counsel for plaintiff cite the case of *Marconi* v. *De Forest, supra*, as adjudicating the validity of the Fleming patent and holding that it is infringed by the De Forest audion. On behalf of defendant it is urged that the opinion rendered therein shows that both sides were suing upon two-electrode patents but as the patents involved in that suit have not been offered in evidence this cannot be definitely determined. It does appear, however, from all of the evidence in the cases between the plaintiff and the De Forest Company that both sides represented to the court and agreed that the inherent qualities of the two-electrode tube and the three-[fol. 89] electrode tube are the same. This being admitted by counsel, the decision, of course, was based upon that conclusion. If this conclusion was not correct, and we think it was not, the decision last cited has no application to the instant case. It should be observed, however, that the case

involved ten patents, of which certain ones belonging to the plaintiff were held valid and infringed and as we understand the opinion it would seem that certain of the De Forest patents were also held valid. But we have nothing before us from which we can determine what was covered by these patents respectively and consequently cannot say how far Judge Mayer's decision went. The decision recites that the plaintiff (Marconi Co.) confessed judgment on two of the De Forest patents, and it is said that "De Forest in his three-electrode audion has undoubtedly made a contribution of great value to the art and by the confession of judgment in respect thereof defendant company may enjoy the just results of this contribution", and a type of the De Forest audion was used by defendant in the case now before us. But it is not necessary for us to determine whether any of the De Forest patents were valid. What we have to determine in this case is whether the De Forest audion and other three-electrode apparatus used by defendant as shown by the findings constituted an infringement. One other matter which should be considered on this point, as we view it, is that a comparison of the apparatus of the De Forest audion, as shown in the diagram in finding LXXV, with the Edison apparatus, as shown in fig. 4 in finding LXX, definitely establishes that the De Forest audion, with the exception of the added third electrode in the form of a grid and the additional circuit attached to the grid, used absolutely nothing but what had been pictured by Edison long before Fleming thought of it; and that the additional apparatus used by De Forest was something that Fleming had never imagined and was not suggested in any way by his patent. What De Forest accomplished thereby could never be effected by the use of the Fleming tube, except by the use of some special additional apparatus never contemplated by Fleming and never put into commercial or practical use.

The defendant not only introduced new features in the apparatus which it used but the apparatus functioned altogether differently from that of Fleming's and produced different and improved results.

Dr. Van der Bijl, a noted radio expert, was quoted with approval by Dr. Miller, a witness in the case, as follows: "In fact, the insertion of the grid into the valve resulted in a device of tremendous potentialities, one that can justly be placed in the same category with such fundamental de-

vices as the steam engine, the dynamo, and the telephone." And also, "It is hardly necessary to say that the insertion of the grid has made the audion a device of immense practical importance and enabled it to perform functions that would otherwise have been impossible."

Plaintiff's expert, Weagant, practically admits that these quotations state the fact correctly, but says that "the two-electrode Fleming valve is the foundation on which this important structure has been reared, and, as has been demonstrated in my recent tests, possesses inherently all of the characteristic capabilities of the three-electrode tube." This statement of Weagant's is the foundation of plaintiff's case. Let us see how it agrees with the facts [fol. 90] shown in evidence and the reasonable deductions that may be drawn therefrom.

We have already shown how different was the function of the three-electrode tube from the two-electrode tube, but Weagant says that the two-electrode tube can be made to function in the same manner "by means of an electrostatic field control of the electron stream." He does not explain how, but it was shown elsewhere in the testimony that it was by means of an electrostatic field being brought close to a specially shaped bulb of the Fleming valve but outside of it, the effect of which was to a greater or less extent to deflect the electron stream from the heated filament. In the De-Forest apparatus the "grid" was placed inside of the bulb and not outside and, as we have seen, functioned in a very different manner. But perhaps the most complete and fatal objection to this claim for the Fleming patent is that while it was shown by tests at the trial that the Fleming tube could be made to amplify in this manner, there was nothing whatever said in the Fleming patent about such an amplification and not the remotest suggestion of setting up an outside field to produce an amplifying or oscillating effect. Apparently no one ever thought of anything of the kind until the three-electrode tube had gone into successful use—in fact, into universal use so far as long distances had to be overcome. After experiments with the three-electrode tube had shown how superior it was not only to the Fleming two-electrode tube but even to the crystal detectors some of which were much more effective than the Fleming apparatus, after a disclaimer had been filed on the Fleming

patent, and after suits had been begun for its infringement; in short after all this had taken place, someone found that some of the same results could be produced with the Fleming valve in the manner described above and demonstrations were made on the trial of cases affecting the De Forest patent. When it comes down to the case before us, we find that years have elapsed since that discovery was made and yet there is not a syllable of evidence to show that this method, which is now said to be inherent in the Fleming patent and by which the same results could be accomplished as by the three-electrode tube, has ever been commercially used, nor is there any evidence that it ever was used in a practical way, although there can be no doubt that the plaintiff would have produced testimony on that point if it could be obtained. On the other hand, although De Forest was probably not conscious of the full limits to which his invention might be extended, it is a matter of common knowledge that the three-electrode tube came into general use for long distance purposes superseding even the best of the crystal detectors. The Government at all times and especially in war times had need of the best which could be obtained and it never used any of the two-electrode tubes. All the tubes which it used were of three electrodes. In fact, only about 700 of the Fleming valve two-electrode tube sets were ever put out, so completely did the three-electrode tube surpass them.

The Circuit Court of Appeals in *Marconi* v. *De Forest*, *supra*, says that in the audion the high-frequency oscillations and their electrical result get into the indicator or battery circuit just as in the Fleming valve. This, we think, is quite incorrect. The audion excluded the high-frequency oscillations but what is more important it used two circuits in transforming the alternating current and functioned alto-[fol. 91] gether differently. It is said that a detector must act on alternating current and that this makes the defendant (De Forest) an infringer although he invented an improved detector. If by the word "detector" is meant the tube containing the heated filament, it is true that an alternating current is used both by Fleming and by De Forest in his audion. But this does not make the audion an infringement for De Forest used it in a different combination, with different apparatus and for a different purpose. It is true

Fleming discovered that Edison's apparatus could be used to transform the alternating current into a direct current, as shown by his article before referred to, but all this was several years before his patent was issued and could not be patented. The audion made use of Edison's apparatus and the discovery that the alternating current was thereby rectified, but beyond this it made use of a new device which was probably the greatest improvement that has ever been effected and upon which all long distance wireless communications still depend.

It is contended that when DeForest introduced the screen grid he merely divided the current which entered the tube and passed in and out of the heated filament and that there was no invention in so dividing it. We are not impressed with this argument. Ever since the possibility of wireless communication in some manner entered the brain of Hertz, scientists have been experimenting to ascertain what could be done with original current to extend the distance in which its effects could be felt or made manifest in a distant apparatus. In so doing, they have strengthened the current by parallel coils and condensers; they have varied it with spark gaps, with greater or less intervening space; they have transformed it from an alternating current to a direct current; and finally, by use of an apparatus in which the screen grid is essential, they have succeeded in amplifying it many thousand times. Today we can hear around the world not merely signals but the voice of man reproduced from the same current that originated in the transmitter, strengthened, transformed, and amplified. If this is not discovery or invention or both, it is difficult to understand what would be.

The other apparatus used by the defendant and alleged to infringe the Fleming patent is referred to in Findings LXXVI, LXXIX, and LXXX. Facts are set forth in these findings which, in our opinion, furnish sufficient reason for holding that such apparatus did not constitute an infringement and we think no useful purpose would be accomplished by repeating the statements contained in the findings.

Our conclusion on the whole is that there has been no infringement of the Fleming patent.

WHALEY, *Judge;* WILLIAMS, *Judge;* LITTLETON, *Judge;* and BOOTH, *Chief Justice*, concur.

[fol. 92] VI. **Final Argument and Submission of Case**

On December 2, 1941, the case was argued and submitted on merits by Mr. Abel E. Blackman, Jr., for plaintiff, and by Mr. Clifton V. Edwards for defendant.

[fol. 93] VII. **Special Findings of Fact, Conclusions of Law and Opinion of the Court by Chief Justice Whaley**—Filed April 6, 1942

Mr. Abel E. Blackmar, Jr. for the plaintiff. *Mr. Richard A. Ford*, and *Sheffield & Betts* were on the briefs.

Mr. Clifton V. Edwards, with whom was *Mr. Assistant Attorney General Francis M. Shea*, for the defendant. *Messrs. J. F. Mothershead* and *Joseph Y. Houghton* were on the briefs.

This case having been heard by the Court of Claims, the court, upon the evidence, and the report of a commissioner, makes the following

SPECIAL FINDINGS OF FACT

1. This is a patent suit filed to recover the reasonable and entire compensation for use by the United States of inventions covered by United States letters patent to Marconi, Reissue No. 11,913; to Lodge, No. 609,154; to Marconi, No. 763,772, and to Fleming, No. 803,684.

The court in its special findings of fact and opinion of November 4, 1935 (81 C. Cls. 671), held and now finds as an ultimate fact that the Marconi reissue patent and the Fleming patent had not been infringed; that the Lodge patent was valid as to claims 1, 2, and 5, and had been infringed, and that the Marconi patent, No. 763,772, was invalid except as to claim 16 thereof, which claim was valid and had been infringed by the United States.

Reasonable and entire compensation is based on the infringement of the Lodge patent and Marconi patent No. 763,772.

[fol. 94] LODGE PATENT NO. 609,154

2. Reasonable and entire compensation with respect to the Lodge patent is limited to apparatus purchased or acquired by the Government during the period extending

from March 8, 1913, when plaintiff first gave notice of infringement to the defendant, to August 16, 1915, when the patent expired.

This period will hereinafter be referred to as "the Lodge accounting period."

3. During the Lodge accounting period the United States purchased and used both complete and incomplete wireless transmitters, receivers, and sets from various contractors, including the plaintiff and its licensees; during that period the United States also acquired such apparatus by manufacturing the same and by assembling it from parts which had been either purchased or manufactured or both. It also purchased or acquired spare parts for such apparatus and auxiliary apparatus, all of which was designed and intended for use as a part of and useful only as a part of such apparatus.

4. During the Lodge accounting period wireless transmitters acquired or purchased by the United States were either of the spark type or the arc type.

The essential elements of a complete spark transmitter comprise a source of electrical power such as a motor generator for providing an alternating current of a particular frequency, usually 500 cycles, the purpose of this frequency being to provide an easily recognizable note or tone to the signals; a transmitter-transformer to step up the voltage; a primary circuit, including a spark-gap, an inductance coil (the primary of the oscillation-transformer), and ordinarily a condenser; a secondary circuit including an antenna, an inductance (the secondary of the oscillation-transformer), and a ground or earth connection; and a key or other suitable signalling means.

The essential elements of an arc transmitter were the same except that the source of electrical power provided a direct current of a proper voltage to operate the arc (usually 750 volts) so that no transmitter-transformer was required, the arc generator taking the place of the spark-gap.

[fol. 95] The essential elements of a complete wireless receiver during the Lodge accounting period and as used by the United States comprised a primary circuit, including an antenna, a ground or equivalent connection, an inductance (the primary of the oscillation-transformer), and ordinarily a variable condenser; a secondary circuit, including an in-

ductance (the secondary of the oscillation-transformer), and ordinarily a variable condenser; a suitable detector (either a crystal or a vacuum tube); in many instances a vacuum tube amplifier; and head telephones. A device known as a ticker was sometimes associated with the secondary circuit.

Except in the case of portable sets and wireless compass transmitters, the antenna was not purchased nor acquired as a part of the wireless apparatus but was always constructed and installed by the United States.

5. Claims 1, 2, and 5 of the Lodge patent, held valid and infringed by the court in its opinion of November 4, 1935, are as follows:

1. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, of a self-inductance coil inserted between them electrically for the purpose of prolonging any electrical oscillations excited in the system and constituting such a system a radiator of definite frequency or pitch.

2. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, of a self-inductance coil inserted between them electrically for the purpose of prolonging any electrical oscillations excited in the system, thus constituting the system a resonator or absorber of definite frequency or pitch, and a distant radiator of corresponding period capable of acting cumulatively.

5. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, of a variably acting self-inductance coil, serving to syntonize such a radiator or resonator to any other such resonator or radiator, whereby signalling may be effected between any two or more correspondingly attuned stations without disturbing other differently attuned stations.

The substance of the Lodge invention, as expressed by the phraseology of these claims, is the tuning of the antenna circuits of radio transmitters and receivers to a definite fre- [fol. 96] quency or wave length by means of a self-induction coil, and to the selective tuning or syntonizing of a given transmitting antenna to a given receiving antenna, to the exclusion of other stations operating on different frequencies or wave lengths.

The basic position of the Lodge patent in the art, and with respect to the original Marconi patent, is defined by the court in its findings of fact and opinion, 81 C. Cls. 671 (Finding XXXVI), in which it is stated that—

Marconi in his patent #586193 apparently did not appreciate the desirability of tuning the primary oscillating circuit by the use of an inductance coil, and did not contemplate varying the effective tuning of the receiver to one of several transmitters.

The American Therapeutic Association publication told how to determine and vary the period of an oscillating circuit by modifying the inductance and capacity.

The patents to Pupin #640516 dated January 2, 1900, filed May 28, 1895; Hutin et al., #838545 dated December 18, 1906, filed May 9, 1894; and Stone #577214, February 16, 1897, filed September 10, 1896, show that the laws of closed resonant circuits in general were known prior to the Lodge invention, but such patents do not show knowledge of the desirability of tuning an open oscillating circuit for Hertzian-wave signalling.

No one prior to Lodge appreciated the desirability of tuning the oscillating circuits of both the transmitter and receiver for the purpose intended and in the manner performed by him. [Italics supplied.]

The selective and adjustable tuning of the antenna circuits as taught by Lodge was of fundamental importance to practical radio or wireless communication during the Lodge accounting period, and there is no satisfactory evidence of any substitute for such invention during this period, the use of which would have resulted in wireless apparatus of any practical utility.

6. All the radio transmitters and receivers and sets purchased or acquired by the United States during the Lodge accounting period utilized the subject-matter of one or more of the Lodge claims referred to in the previous finding, and such utilization gave to the apparatus substantially its entire utility and market value.

7. The tabulation on the following pages, and which is a [fol. 97] part of this finding, sets forth in itemized form the radio apparatus acquired by the United States during the

Lodge accounting period without the license or consent of the plaintiff.

Certain contracts, abstracts, and other documents, plaintiff's Exhibits 51, 57, 63, 65, 66, 406, 407, 408, 408-A to 408-D, inclusive, 432, and 459, which are by reference made a part of this finding, comprise the sources of information for this table, and the numbers given in the first column of the table identify the various items set forth in the contracts and abstracts.

The procedure which was followed in the present case to prove what infringing apparatus was used or manufactured by or for the defendant was as follows: Plaintiff filed motions for calls on the Navy Department, War Department, and the General Accounting Office for various documents, including the complete files in the General Accounting Office with respect to certain specified contracts for the purchase of radio apparatus. In order to obviate the expense of photostatic copies, it was agreed that the requested documents would be made available to a representative of the plaintiff who would examine them and make abstracts of their contents, which was done. These abstracts were submitted to a representative of the defendant for correction and the addition of any further desired material. The abstracts were then accepted in evidence in lieu of certified copies of the documents themselves. To facilitate the accounting proceeding, it was arranged that, in lieu of further formal motions for calls, plaintiff might make informal requests for the production of documents from defendant's files and that when such documents were located, the defendant would permit plaintiff's representative to examine them and make abstracts thereof in the manner above described.

8. In certain of the tabulated items liquidated damages totalling about 1% of the contract price given in the tabulation on pages 6 and 7 were assessed against the various contractors.

Such penalization of plaintiff's competitors has not been taken into account and the original contract price has been used in all instances to determine the market value.

Item	Nature of apparatus	Number of transmitters	Number of receivers	Contract price	Value of transmitters	Value of receivers	Value of parts	Entire market value
31	2 5-kw. transmitters, 4 receivers	2	4	$7,198.00	$6,198.00	$1,000.00	....	$7,198.00
32*	1 arc transmitter, 2 receivers	1	2	52,801.04	23,080.00	1,455.00	....	24,535.00
33	1 transmitter	1	...	7,500.00	7,500.00	....	....	7,500.00
34	1 transmitter, 1 receiver	1	1	2,340.00	2,090.00	250.00	....	2,340.00
35	4 transmitters, 8 receivers	4	8	20,000.00	18,000.00	2,000.00	....	20,000.00
36	2 transmitters, 4 receivers	2	4	8,474.00	7,474.00	1,000.00	....	8,474.00
41*	2 transmitters, 4 receivers	2	4	9,500.00	8,500.00	939.00	....	9,439.00
48	3 30-kw. arc transmitters, 3 receivers	3	3	31,769.00	30,494.00	1,275.00	....	31,769.00
49	2 arc transmitters, 2 receivers	2	2	15,250.00	14,400.00	850.00	....	15,250.00
50*	5 arc transmitters with receivers	2	2	52,040.00	19,966.00	850.00	....	20,816.00
Pl. Ex. 407	1 receiver	...	1	425.00	....	425.00	....	425.00
52	17 transmitters, one with motor generator	17	...	18,467.75	18,467.75	....	....	18,467.75
A-1	5 quenched spark-gaps	...	...	1,800.00	....	....	$1,440.00	....
A-3	50 rotary tickers	...	...	2,000.00	....	....	2,000.00	....
A-4	4 transmitters	4	...	1,450.00	1,450.00	....	....	1,450.00
A-6	2 transmitters, 4 receivers	2	4	10,000.00	9,000.00	1,000.00	....	10,000.00
A-10	15 receivers	...	15	4,080.00	....	4,080.00	....	4,080.00
A-11	1 5-kw. inductor type radio alternator	...	...	716.00	....	....	716.00	....
A-14	1 30-kw. arc transmitter with spare parts	1	...	8,034.12	6,990.10	....	1,044.02	6,990.10
A-15	64 ticker detectors	...	...	2,731.40	....	....	2,731.40	....
A-16	34 ultra-audion detectors, 4 receivers	...	4	7,625.00	....	2,200.00	4,200.00	2,200.00
A-19	10 transmitters, 10 receivers	10	10	10,000.00	9,000.00	1,000.00	....	10,000.00
A-20	1 transmitter	1	...	5,775.00	5,775.00	....	....	5,775.00
A-21	1 motor generator	...	...	587.00	....	....	587.00	....
A-22	3 motor generators, 3 transformers	...	...	3,450.00	....	....	3,450.00	....
A-23	21 receivers	...	21	4,084.50	....	4,084.50	....	4,084.50
A-24	1 transmitter	1	...	1,096.00	1,096.00	....	....	1,096.00
A-25	20 motor generators, 20 transformers	...	...	19,075.00	....	....	19,075.00	....
A-26	Parts for radio spark transmitter	...	...	1,957.66	....	....	1,451.20	....
A-28	3 transmitters	3	...	3,825.00	3,825.00	....	....	3,825.00
A-29	Transmitter parts, 10 receivers	...	...	1,430.00	....	....	870.00	....

A-32*	2 transmitters, 4 receivers	1	4	10,000.00	4,500.00	1,000.00	....	5,500.00
A-33	15 transmitters, 15 receivers	15	15	15,000.00	13,500.00	1,500.00	....	15,000.00
A-34	2 transmitters, 2 receivers	2	2	8,512.80	7,732.80	780.00	....	8,512.80
A-35*	30 receivers	...	23	9,380.00	....	7,462.00	....	7,462.00
A-36	50 receivers	...	50	6,000.00	....	6,000.00	....	6,000.00
[fol. 99]								
A-37*	6 5-kw. transmitters with spare parts	6	...	24,900.00	24,000.00	....	....	24,000.00
A-38*	3 5-kw. transmitters	3	...	12,553.00	12,103.00	....	....	12,103.00
A-39*	5 5-kw. transmitters	5	...	19,625.00	14,718.75	....	....	14,718.75
A-53	4 receivers	...	4	1,560.00	....	1,560.00	....	1,560.00
A-54	14 receivers	...	14	4,550.00	....	4,550.00	....	4,550.00
A-55	15 receivers	...	15	1,938.75	....	1,938.75	....	1,938.75
A-56	8 2-kw. transmitters without power supply; 8 motor generators	8	...	12,400.00	12,400.00	....	....	12,400.00
A-80	50 oscillation transformers	...	...	3,000.00	....	....	3,000.00	....
B-15	1 10-kw. transmitter without motor generator	1	...	4,200.00	4,200.00	....	....	4,200.00
B-24	40 receivers	...	40	2,400.00	....	2,400.00	....	2,400.00
B-43	Parts for quenched spark-gap transmitter	...	...	1,132.80	....	....	1,129.20	....
B-44	25 spark-gaps for transmitters	...	...	550.00	....	....	550.00	....
C-1	50 audion detectors and amplifiers	...	...	12,250.00	....	....	12,005.00	....
C-2	24 audion detectors	...	...	1,200.00	....	....	1,200.00	....
Pl. Ex. 459	4 receivers	...	4	1,017.29	....	1,017.29	....	1,017.29
A-27	1 transmitter, 1 receiver	1	1	2,450.00	2,020.00	430.00	....	2,450.00
Tuckerton transmitter	1 transmitter	1	...	8,000.00	8,000.00	....	....	8,000.00
Eaton receivers	3 receivers	...	3	750.00	....	750.00	....	750.00
		102	260	....	296,480.40	51,796.54	56,448.82	348,276.94

* See Finding 10 for explanation of items marked with asterisk.

[fol. 100] 9. Certain of the items of the above tabulation are for parts of sets. A more detailed explanation of these items follows:

(*Item A-1*).—This item is for five quenched spark-gaps at a total contract price of $1,800. The contract file shows payment during the Lodge accounting period for four of the five gaps, the total amount of the payment being $1,440.

Quenched spark-gaps were designed and intended for use as generators of high-frequency current for radio transmission, and their sole utility is for this purpose.

(*Item A-3*).—This item covers a contract to the Federal Telegraph Company dated August 18, 1913. The contract called for fifty rotary tickers at a contract price of $2,000, which was paid in full during the Lodge accounting period.

A rotary ticker is a form of wireless detector primarily designed to detect continuous or undamped waves, although it will also receive damped waves. A rotary ticker is a part of a radio receiver and it has no use or utility other than in the reception of radio signals impressed upon the antenna of a receiving set.

(*Item A-15*).—This item covers a contract with the Federal Telegraph Company dated March 27, 1914, and is for sixty-four ticker detectors, including spare parts, at a total contract price of $2,731.40. The contract file shows payment during the Lodge accounting period of the contract price with the exception of $13.90, which was withheld as liquidated damages.

The function and utility of ticker detectors have been discussed in connection with the prior item.

(*Item A-11*).—This item covers a contract with the Atlantic Communication Company dated September 22, 1913, for one 5-kw. inductor type radio alternator at a contract price of $716. The sum of $715.28 was paid during the Lodge accounting period, seventy-two cents having been withheld as liquidated damages.

An inductor type radio alternator is the source of high-frequency electrical energy for a radio transmitter, and during the Lodge accounting period such a device was useful only as a part of a radio transmitter.

(*Item A-16*).—This item calls for ultra-audion detectors which were radio detectors utilizing a form of oscillating

[fol. 101] audion. Such device is not useful in and of itself but only for use as a part of a radio receiver. The contract price of the thirty-four detectors was $4,200 and the contract price of the four receivers, $2,200. The $1,225 difference between the contract price of $7,625 and the $6,400 is for certain radio tubes or bulbs for which plaintiff does not claim compensation.

(*Item A—21*).—This item covers a contract with the Atlantic Communication Company dated June 10, 1913, and covers a motor generator, including a 5-kw. 500-cycle inductor type radio alternator. The contract price was $587, of which $579.37 was paid during the Lodge accounting period, the balance of $7.63 being withheld as liquidated damages. The motor generator is a device designed solely for the production of a 500-cycle alternating current as a source of energy in a radio transmitter, the 500 cycles being for the sole purpose and function of imparting to the transmitted radio signal a singing or musical tone characteristic, easily recognizable by the receiving operator through static. The sole utility of these motor generators at the time of the Lodge accounting was for the generation and transmission of a radio signal from a transmitting antenna.

(*Item A—22*).—This item covers a contract with F. Lowenstein, dated May 13, 1913. The contract price was $2,700 for the motor generators and $750 for the transformers, or a total of $3,450.

The contract file shows payment during the Lodge accounting period of $3,340.40, the sum of $109.60 having been withheld as liquidated damages. The purpose and function of the motor generators have been detailed in the prior item, and the sole function and utility of the transformers was to step up the voltage of the 500-cycle current from the motor generators to a suitable voltage for operating the closed oscillation circuit of the transmitter, which produces the high-frequency oscillations which are fed into the antenna circuit.

(*Item A—25*).—This item covers a contract with the Atlantic Communication Company, dated June 2, 1913, and was directed to twenty radio motor generator sets of 5-kw. and 2-kw. sizes, together with the spare parts for same, and

[fol. 102] twenty transformers for use with the same, the total contract price being $19,075.

The contract file shows payment of $18,796.44, the sum of $278.56 having been withheld as liquidated damages.

The function and utility of the motor generators and transformers have been detailed in the two prior items.

(*Item A-26*).—This item covers a contract with the Atlantic Communication Company dated June 3, 1913, and called for various parts and elements relating to a transmitting set, at a total contract price of $1,957.66.

The following items depend for their entire utility in the generation of high-frequency current for transmission from a radio antenna:

1 primary variometer	371.20
1 5-kw. 500-cycle motor generator	950.00
1 5-kw. 500-cycle transformer	130.00
	1,451.20

(*Item A-29*).—This item covers a contract with the National Electrical Supply Company dated January 23, 1914, for various radio transmitter parts, such as transformers, high-tension condensers, spark-gaps, oscillation transformers, and receiving sets, at a total price of $1,430. These parts have no other utility than the generation of high-frequency current for use in a radio transmitting antenna.

The contract file shows that the sum of $870 was paid during the Lodge accounting period covering the transformers, spark-gaps, and parts. There is no evidence as to the delivery of or payment for the condensers or receiving sets. The abstract of this contract states as follows:

No record of completion of delivery of order as shown by contract files.

(*Item A-80*).—This item covers a contract with the National Electrical Supply Company dated September 17, 1914, and was for fifty oscillation transformers at a total cost of $3,000. Such transformers were used as a part of the radio frequency circuits of wireless transmitters, and either both coils of the transformer were used in the antenna circuit as a loading coil or the secondary coil of the transformer

[fol. 103] was used in the antenna circuit, in either instance to tune that circuit.

The contract file shows payment of the full contract price to the contractor during the Lodge accounting period.

(*Item B-43*).—This item refers to a contract with the National Electrical Supply Company dated November 14, 1914, and which called for an incomplete set of parts for a quenched-gap wireless transmitter, the aggregate contract price being $1,132.80. The parts have utility only in furnishing high-frequency current to a radio transmitting antenna.

The payment made to the contractor, however, during the Lodge accounting period was $1,129.20, due to the fact that certain small parts were furnished by the defendant. There is no proof as to when this group of small parts was acquired by the defendant.

(*Item B-44*).—This item covers a contract with William A. Knapp dated December 2, 1914, and is for twenty-five spark gaps at a total price of $550. A spark gap is an apparatus the sole utility of which, during the Lodge accounting period, was to enable the transmitter condensers to become charged and then to subsequently discharge into the local oscillating circuit with a consequent generation of high-frequency current which was transferred to the antenna circuit.

The entire amount of the contract was paid to the contractor during the Lodge accounting period.

(*Item C-1*).—This item covers a contract with the De-Forest Radio Telephone and Telegraph Company dated April 30, 1915. It included among other things fifty combined audion detectors and one-step amplifiers at a total price of $12,250. These detector amplifiers had their sole utility in the detection and amplification of the relatively weak energy received on a receiving antenna.

The contract file shows payment to the contractor during the Lodge accounting period of the sum of $12,005, covering the cost of forty-nine of the detector amplifiers.

(*Item C-2*).—This item covers a contract with the De-Forest Radio Telephone and Telegraph Company dated June 30, 1915, and included among other things twenty-[fol. 104] four audion detectors at a total price of $1,200. The utility of these detectors as to circuits and function

was the same as the detector portions of the detector amplifiers of the previous item (C-1).

The contract file shows payment in full for the twenty-four audion detectors during the Lodge accounting period.

10. In certain other items of the tabulation indicated by a single asterisk the entire market value is less than the contract price. A detailed explanation of these items is as follows:

(*Item 32*).—This item covers a contract for high-power radio installation for the Naval Station at Caimito, Panama Canal Zone. The total contract price was $52,801.04 and included such general items as powerhouse machinery, powerhouse switchboard, wiring from powerhouse to operating house, and powerhouse wiring. The price of the "wireless apparatus" was $24,535, which amount was paid in full during the Lodge accounting period. The elements comprising the "wireless apparatus" and the prices of each are as follows:

Transmitter

Helix	$3,000.00
Poulsen arc	11,210.00
Wave change switch and antenna	2,000.00
2 relay keys	4,500.00
2 sets choke coils	500.00
Switchboard	1,470.00
Antenna entrance	400.00
Total cost of transmitter	23,080.00

Receivers

1 receiving cabinet, 600-3,000 m	450.00
1 receiving cabinet, 2,000-10,000 m	450.00
4 head receivers	20.00
2 110 v. tickers	100.00
1 6 v. ticker	50.00
1 triple audion amplifier	385.00
Total cost of receivers	1,455.00

(*Item 41*).—This item is for two radio sets at a contract price of $9,500. Payment of $9,439 was made during the Lodge accounting period, a balance of $61 being withheld

[fol. 105] because the defendant itself supplied four telephone head sets for the receivers, and the amount payable to the contractor was therefore reduced by this amount. There is no evidence to show whether the telephone head sets were acquired by the Government within the Lodge accounting period.

(*Item 50*).—This item calls for five 30-kw. arc radio sets complete with receivers at a total contract price of $52,040. The contract is in evidence as plaintiff's Exhibit 406, and shows that two of the five sets were delivered during the Lodge accounting period. Attached to the contract file were three receipts which referred to three vouchers by number and stated that they were missing. On the first page of the contract and with reference to these same three vouchers, the following memorandum appeared:

Contract 350 P. 3 Abstracted 3-14-38 GHC
On first page of contract is the following memorandum in red ink:

878	4/15 NY	19,016.00	
1731	4/15 NY	1,200.00	
2262	1/16 NY	600.00	20,816.00

There is no proof of delivery of or payment for the remaining three sets during the accounting period, which expired August 16, 1915.

(*Item A-32*).—This item covers a contract, plaintiff's Exhibit 57, which called for two 5-kw. wireless sets each with two receivers, the contract price being $10,000. The contract file shows delivery and satisfactory operating condition of one of the transmitters, together with partial payment of the same, by December 29, 1912, and therefore prior to the Lodge accounting period. Payment for the second set (contract price $5,000) and the four receivers was made during the Lodge accounting period. The receivers delivered under this contract were of the IP-76 type and were of an average price of $250 each.

(*Item A-35*).—This item covers a contract calling for thirty radio receivers at a total contract price of $9,380. The contract file shows delivery of and payment during the Lodge accounting period for twenty-three of the receivers.

There is no proof of delivery of or payment for the remaining seven receivers, the contract price for which was $1,918.

[fol. 106] (*Item A–37*).—This item covers a contract calling for six 5-kw. wireless transmitters with spare parts. The total contract price was $24,900. The contract file shows payment to the contractor during the Lodge accounting period of $24,000, which is the full contract price less $900 "for material supplied by the Navy Department." There is no satisfactory evidence as to when this material was acquired by the defendant or whether such material is already included and formed a part of the material listed in the tabulation on pages 6 and 7.

(*Item A–38*).—This item called for three 5-kw. wireless transmitters at a contract price of $12,553. The contract file shows $450 taken from the full contract price for apparatus (short-circuiting switches) supplied by the defendant. There is no proof as to when such apparatus was manufactured or acquired by the defendant.

(*Item A–39*).—This item covers a contract with F. Lowenstein dated August 4, 1914, which called for five 5-kw. wireless sets exclusive of receivers and wave meters, at a contract price of $19,625.

The contract file shows delivery of the five sets and payment to the contractor during the Lodge accounting period of 75% of the contract price, viz, $14,718.75. There is no record of payment of the remaining 25% and no record of this being withheld as liquidated damages.

11. The item on the tabulated list appearing on pages 6 and 7 designated "Plaintiff's Exhibit 459," refers to four receivers, and lists under the contract price and the entire market value the amount of $1,017.29. These four receivers were manufactured at the Washington Navy Yard and completed July 13, 1915 (within the Lodge accounting period), at a total actual cost of $1,017.29.

Plaintiff's Exhibit 459 is the Navy Yard summary of the estimated and actual costs of these sets.

(*Item A–27*).—This item refers to one transmitter and one receiver covered by a contract with the Telefunken Company dated January 29, 1913, for installation on the U. S. Army transport *Liscum*, the contract price being $2,450. While the abstract of this contract shows no record

of payment in the contract file, plaintiff's Exhibit 428, Item [fol. 107] 9, has reference to an official notice referring to this contract and indicating that this set was inspected and accepted.

(*Tuckerton arc transmitter*).—In 1914 the Navy Department installed a 60-kw. arc transmitter at Tuckerton, New Jersey, which transmitter was subsequently removed to the Naval Radio Station at Arlington, Virginia. The estimated market value of this transmitter is $8,000.

(*Eaton receivers*.—Three radio receivers were constructed or assembled from parts during the years 1913-1915; the first was assembled and used at Arlington, the second at the Naval Laboratory, and the third at Tuckerton.

These receivers were assembled from parts already on hand at the localities specified.

The approximate market value of these receivers was $750.

12. Certain apparatus, designated as follows, has been omitted from the itemized list of aparatus appearing on pages 6 and 7 as not properly coming within the accounting:

(*Item A-5.*)—This item calls for one arc transmitter and one receiver for a contract price of $5,500. The contract was with the Federal Telegraph Company under date of November 2, 1914.

The contract file contains no record either of delivery of the apparatus or payment therefor.

(*Item B-20.*)—This item covers a War Department order dated October 10, 1913, to the National Electrical Supply Company for fifteen helices, fifteen spark-gaps, and fourteen receiving sets, the total of the contract price being $982. With the exception of the fifteen helices, there is no satisfactory evidence either of delivery of or payment for these items within the accounting period.

(*Item B-21.*)—This item covers a War Department order to the National Electrical Supply Company dated October 22, 1913, for thirteen helices, fifteen spark-gaps, and five receiving sets at a contract price of $445. There is no satisfactory evidence either of delivery of or payment for these items within the accounting period.

(*Item B-52.*)—This item covers a War Department order 13967 to the National Electrical Supply Company dated

October 27, 1913. The order covers four spark-gaps, three [fol. 108] helices, and nine receiving sets at a total contract price of $449. There is no satisfactory evidence either of delivery of or payment for these items within the accounting period.

13. During the Lodge accounting period the plaintiff granted certain nonexclusive licenses to others to manufacture and sell wireless apparatus embodying the invention of the Lodge patent. These licenses (plaintiff's Exhibits 360 and 447, which are by reference made a part of this finding) were under and included both the Lodge patent and the Marconi patent No. 763,772 and are herewith summarized as follows:

(a) Under date of July 14, 1914, to National Electrical Supply Company. The license was under the Lodge patent and Marconi patent and granted a nonexclusive license to manufacture 1/4-kilowatt portable wireless telegraph sets and sell them to the United States; the royalty provided for therein was $250 a set. The license was terminable by the plaintiff on 30 days' notice, and was canceled under date of January 24, 1916.

(b) Under date of April 15, 1915, to the National Electrical Supply Company. The license was under the same two patents and granted a nonexclusive license to manufacture wireless telegraph apparatus and sell it to the United States. It was stated to amend, modify, and supplement the above-mentioned agreement of July 14, 1914. The royalties provided for therein were 20 percent of the gross selling price on all sets having a capacity up to and including one kilowatt; 25 percent thereof on all sets between one and three kilowatt capacity, and 33 1/3 percent thereof on all sets above three kilowatt capacity.

Article 12 of this license agreement defines in the following phraseology the base to which the license fee is applied:

Twelfth. In order to prevent any dispute between the parties hereto as to the license fee due and payable hereunder, it is agreed that the term "apparatus" or "set" as used in this agreement, shall cover and include only the following elements:

1. Primary Generator of Mechanical Power or a Primary Generator of direct or alternating electric current.

2. Switchboard (or) starting Device.
3. Transformer.
4. Spark gap and cooling device.

[fol. 109] 5. Oscillation producer (arc, Spark or other).

6. Transmitting condenser.
7. Transmitting oscillation transformer.
8. Antenna inductance.
9. Operating key and (or) equivalent relay.
10. Antenna switch.
11. Receiving oscillation transformer.
12. Receiving condenser.
13. Detector.
14. Receiving oscillation producer.

Article 12 of this license also states that if the license should sell any of the elements listed less than the whole number, then the licensee should pay to the licensor the rate of license fee previously provided. This license was terminable by either party on 30 days' notice and was canceled under date of January 24, 1916.

(c) Under date of October 15, 1914, to National Electric Signaling Company. The license was a cross-licensing agreement by which the plaintiff granted to the Signaling Company a nonexclusive license to make, use, lease, and sell wireless telegraph and wireless telephone apparatus embodying the inventions of the Lodge patent, the Marconi patent No. 763,772 and a Freeman patent, No. 773,069. Where apparatus was sold the royalty was 20 percent of the gross selling price, including sales to the United States, except that the royalty was 30 percent on sales for use on foreign ships.

The base upon which the royalty was payable was defined as the same elements listed in Article 12 in the license agreement of April 15, 1915, with the National Electric Signaling Company, with the exception that item or element No. 1 is specified as "motor generator." This license agreement also specified that if either party should sell any of the elements listed less than the whole number the licensee should pay to the licensor 20 percent of the selling price of the elements sold.

The license was terminable by the plaintiff during a certain period, on 90 days' notice, and notice of cancellation thereof was given by plaintiff on March 1, 1917, such cancellation taking effect on May 30, 1917.

[fol. 110] This agreement was entered into to settle litigation which was pending between the parties, including a suit by plaintiff against the National Electric Signaling Company on the Lodge and Marconi patents (*supra*) wherein both of these patents had been held by the United States District Court for the Eastern District of New York valid and infringed as to certain claims thereof. The agreement contained a release from all claims for damages and profits for past infringement.

The above-mentioned Freeman patent was never adjudicated. The apparatus disclosed in that patent has never gone into use and the disclosure thereof was not embodied in any apparatus purchased, acquired, or used by the United States.

(d) Under date of July 26, 1915, to Clapp-Eastham Company. The license was under the Lodge and Marconi patents (*supra*) and granted a nonexclusive license to manufacture wireless telegraph apparatus and sell it to the United States and to amateurs; the royalty provided for therein was 20 percent of the listed catalogue or gross selling price of each set.

The base upon which the royalty was to be determined was defined to include the same listed elements as are contained in Article 12 of the license agreement of April 15, 1915, with the National Electrical Supply Company. This agreement also carried the clause that if the licensee should sell any of the listed elements less than the whole number, the royalties should be those which were provided, viz, 20 percent on all sets sold to the Government of the United States.

This license was subsequently canceled, but there is no evidence as to its date of cancellation.

14. Following the expiration of the Lodge patent on August 16, 1915, the plaintiff granted numerous nonexclusive licenses under the Marconi patent alone. These licenses, copies of which are contained in plaintiff's Exhibit 447, included licenses granted to William J. Murdock & Company, Sears, Roebuck and Co., A. W. Bowman & Company, and a new license to the Clapp-Eastham Company (for prior license to Clapp-Eastham Company covering both

[fol. 111] Lodge and Marconi patents at 20 percent royalty, see Finding 13 (d)).

The license fee or royalty provided for in these subsequent license agreements was 10 percent of the lowest selling price on all sets sold to amateurs.

15. A fair and reasonable royalty for the use of the invention or inventions, as defined in claims 1, 2, and 5 of the Lodge patent and during the accounting period, is 10 percent of the selling price or market value of the radio transmitters and receivers, including such apparatus as is dependent upon the inventions thus defined for its utility.

16. A reasonable and entire compensation for the use of the Lodge invention is 10 percent of the entire market value of the apparatus tabulated on pages 6 and 7, or $34,827.70, plus an amount measured by interest at 5 percent per annum, not as interest but as part of the entire or just compensation, on $34,827.70 from August 16, 1915, to date of payment of the judgment.

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17. The original petition in this case having been filed on July 29, 1916, and supplemental amended petitions having been filed on May 21, 1919, and June 15, 1922, the accounting period with respect to the Marconi patent, claim 16 of which was held valid and infringed, extends from July 29, 1910, to November 20, 1919, at which time plaintiff assigned the patent. Claim 16 relates to radio receiving circuits.

18. Radio receiving circuits during the period of the accounting and as disclosed and claimed in the Marconi patent comprised two circuits—the open circuit and the closed circuit.

The open circuit consisted of the elevated wire or antenna and a ground connection, together with certain associated tuning instrumentalities. The closed circuit comprised certain tuning instrumentalities and was connected to a detector apparatus to enable the received signals to be rendered audible to the operator.

The open and closed circuits were associated or coupled to each other so that a transfer of energy could take place from the open circuit to the closed circuit. This coupling [fol. 112] means in general comprised a coupling trans-

former, the primary winding of which was associated with the open circuit and the secondary of which was associated with the closed circuit.

19. All radio circuits, whether of open circuit or closed circuit type, inherently possess two electrical characteristics, i. e., inductance and capacity, and the natural frequency or periodicity of a circuit is dependent upon the square root of their product. Besides the inherent capacity and inductance of a circuit, the circuits also generally contained additional capacity and inductance, either of fixed or adjustable value.

An adjustable capacity during the accounting period usually consisted of a condenser having a series of fixed plates interleaved with a series of movable or adjustable plates so that the capacity value could be altered by the extent of the contiguous area of the plates. An adjustable inductance usually consisted of a circular coil on a form, either having taps brought out to a switch or having a movable contact adjacent the turns of the coil whereby more or less turns could be included in the circuit.

By the adjustment of either or both of these two instrumentalities the periodicity of the circuit with which they were associated could be altered or tuned. As the variation of the capacity of the condenser is continuous throughout its range, whereas the variation of inductance is by steps only (either by single turns or by multiples thereof), it follows that finer or more accurate tuning may be obtained by the use of a variable condenser.

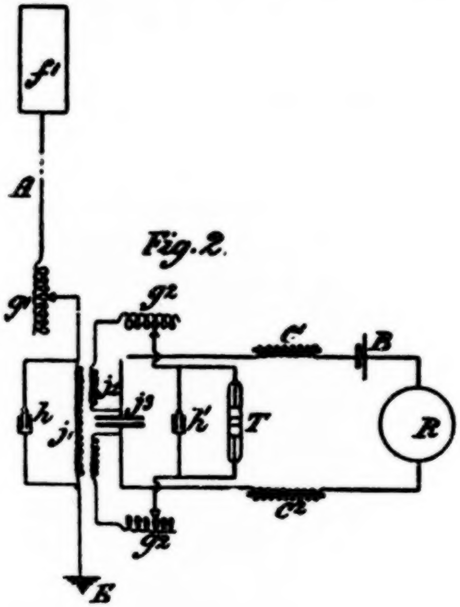
In the utilization of such circuits for receiving purposes, during the accounting period the operator usually relied upon adjustment of the inductance for coarse or preliminary tuning and the condenser for subsequent fine adjustment.

20. Claim 16 of the Marconi patent, held valid and infringed by the court in its opinion of November 4, 1935, is as follows:

At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, *an adjustable con-* [fol. 113] *denser in a shunt connected with the open circuit*

and around said transformer-coil, a wave-responsive device electrically connected with the other coil of the oscillation transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described. [Italics supplied.]

As shown in Fig. 2 of the Marconi patent, herewith reproduced, the claim refers to a receiving apparatus in which



the principal elements are an open or antenna circuit adapted to receive the radiated energy from a transmitting station, and a closed circuit coupled to the open circuit by means of an oscillation transformer, the closed circuit being adapted to deliver energy to a wave-responsive device or a detector. The patent discloses means for adjusting or tuning the periodicity of both circuits with respect to each other and to the periodicity of the radio impulses received on the antenna, so that for any selected wave length or frequency of the received energy the effect on the wave-responsive device will be a maximum.

[fol. 114] These means as disclosed in Fig. 2 of the patent comprise, for the antenna circuit, an adjustable inductance g^1 and an adjustable capacity or condenser h in shunt with

the primary winding j^1 of the oscillation transformer; and for the closed circuit the adjustable inductances g^2 g^7.

21 The Marconi patent describes the preferred construction of the condenser h as—

one provided with two telescoping metallic tubes separated by a dielectric and arranged to readily vary the capacity by being slid upon each other.

The mode of operation and function of such a construction is to provide variation in the periodicity of the open or primary circuit with which the adjustable condenser is associated. In this connection the patent states—

The capacity and self-induction of the four circuits—i. e., the primary and secondary circuits at the transmitting-station and the primary and secondary circuits at any one of the receiving-stations in a communicating system—are each and all to be so independently adjusted as to make the product of the self-induction multiplied by the capacity the same in each case or multiples of each other—that is to say, the electrical time periods of the four circuits are to be the same or octaves of each other.

The degree of variation effected in the periodicity of the open circuit by the adjustable condenser is dependent upon the constants of the associated circuit (inductance and capacity) and upon the maximum-minimum values of the condenser capacity.

The size and spacing of the cylinders, and therefore the maximum and minimum values of the capacity, are not specified, but left to the design of those skilled in the art.

22. While the patent specifically states that the adjustment of the self-inductances and capacity of any or all of the four circuits can be made in any convenient manner and by employing various arrangements of apparatus, it also indicates by way of example certain preferred values of inductance and capacity, and transformer construction (size of wire and number of turns, etc.) for six specified tunes or wave lengths.

[fol. 115] These values are given in tabular form and include the number of turns in the inductances and the capacity in microfarads of the condensers. These data, so

far as the transmitting-station is concerned, give the length of the aerial conductor or antenna, and therefore indirectly give its inductance and capacity. The data with respect to the receiving antenna are not given.

While six specified tunes or wave-lengths are given by way of example, the Marconi invention, as disclosed in the specification and as defined in claim 16, is not limited to any specified wave-lengths or frequencies.

23. The court in its opinion of November 4, 1935, held and now finds that the receiving apparatus of the Kilbourne & Clark Company and that made by the Telefunken Company infringed claim 16 of the Marconi patent. The circuits of these two receivers are reproduced on page 24, and in each of the circuits the condenser h is in a shunt connection with the open circuit and around the primary of the transformer coil, in the Kilbourne & Clark circuit the tuning condenser being in parallel with the load coil and primary. The condenser h is also shown in dotted position in series with the antenna lead. This dotted position, however, is merely indicative of an alternative arrangement of these circuits in which the condenser h may be used in series connection instead of shunt connection.

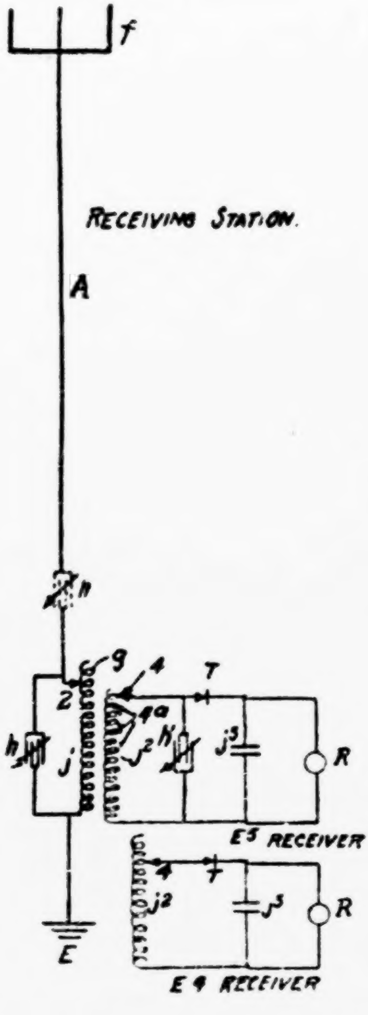
24. During the Marconi accounting period the United States purchased, acquired, or manufactured and used wireless receivers and receiving tuners having circuits in which an adjustable condenser was utilized or adapted for shunt connection with the open circuit and around the primary of the transformer coil. The adjustable condenser in such a circuit had the function and effect similar to that possessed by the adjustable condenser of the Marconi patent and in the Telefunken and Kilbourne & Clark sets found by the court to infringe and referred to in the previous finding, and was for the purpose of varying the periodicity of the primary circuit with which it was associated.

These sets are listed in the itemized schedule forming a part of Finding 32.

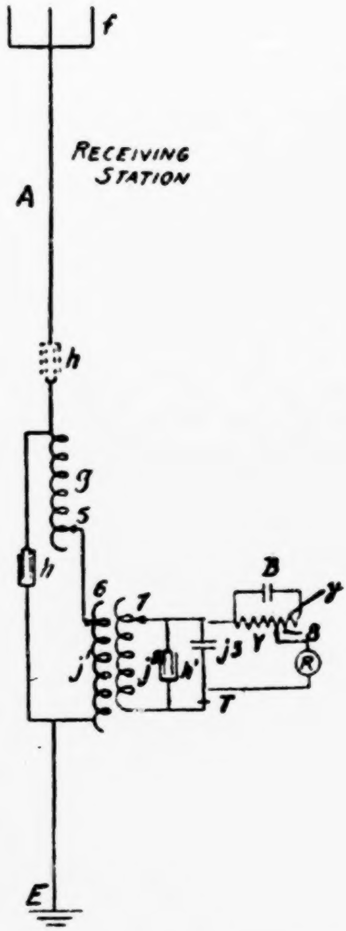
25. The contract cost of the sets thus acquired by the Government in many instances relates to the complete receiver [fol. 116] and includes detector devices and electrical apparatus more particularly directed to an effect on a signal subsequent to its passage through the tuner portion of the

receiving set, and such devices do not properly come within the accounting.

TELEFUNKEN TYPE



KILBOURNE & CLARK TYPE



Due to the difficulty of segregating the costs of the tuner portion of a receiving set from the remainder of the associated apparatus it is impossible to use the cost of the sets as a basis in establishing a fair and reasonable compensation. [fol. 117] 26. If the defendant had not utilized or made provision for the utilization of the shunt condenser connection as exemplified in the Telefunken and Kilbourne & Clark

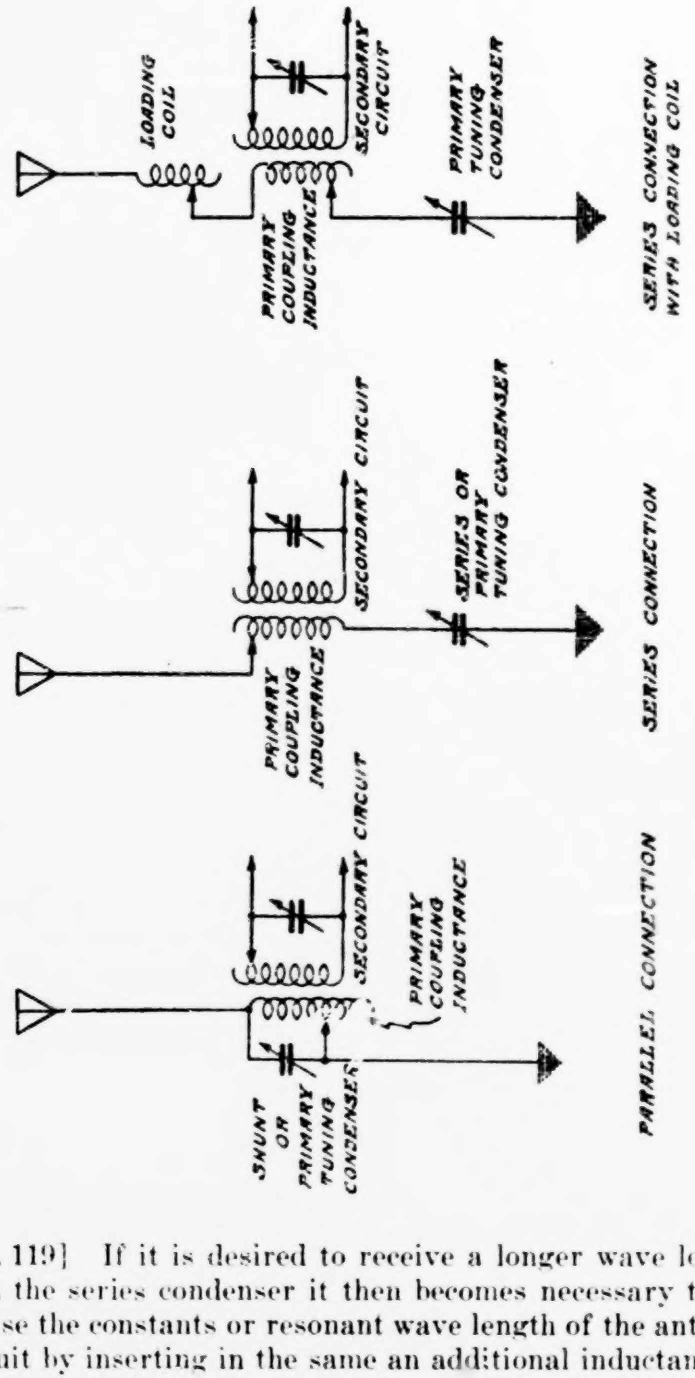
sets and covered by claim 16 of the Marconi patent, it would have been possible to accomplish substantially the same basic results by the use of another type of tuning circuit, but at an increased cost. Compensation may therefore be arrived at by ascertaining the monetary value by a comparison of these circuits.

27. The above-mentioned comparison involves the shunt circuit condenser connection hereinafter referred to as the "parallel connection" (the terms "shunt" and "parallel" being synonymous in electrical parlance), and a circuit herein termed the "series connection." Three figures are reproduced on the following page for the purpose of presenting certain effects in these comparative circuits.

The middle diagram thereof is illustrative of the series connection and shows an antenna circuit connected to one end of the primary of the coupling transformer, the opposite end of the coupling transformer being connected to the ground through a tuning condenser connected in series with the transformer winding. In this center diagram, as in the other two diagrams, the secondary circuit is shown as including only the secondary winding of the transformer and the secondary tuning condenser, the remaining elements of this circuit, such as the detecting devices and associated circuits, being omitted from these diagrams for simplification.

With the arrangement in the primary circuit as shown in the middle diagram and regardless of the maximum value of the condenser, no longer wave length can be received than could be received by omitting the condenser and connecting the primary transformer winding directly to ground, a condenser of relatively large capacity having the same effect on this circuit as an uninterrupted conductor from the lower end of the primary winding to the ground.

In other words, an adjustable condenser connected in series, as exemplified in the diagram, can be used to shorten the natural resonant wave length of the antenna circuit, but cannot lengthen it beyond what would be the resonant wave length if the condenser were not present. The maximum wave length which can therefore be received by a primary [fol. 118] circuit with the series condenser connection is dependent upon the constants (inductance and capacity) of the antenna circuit.



[fol. 119] If it is desired to receive a longer wave length with the series condenser it then becomes necessary to increase the constants or resonant wave length of the antenna circuit by inserting in the same an additional inductance in the form of what is known in the art as "a loading coil." By addition of this inductance the natural periodicity of the

antenna circuit is slowed down or decreased, thereby enabling the antenna circuit to become resonant to longer wave lengths.

It was the practice during the accounting period to use this method in the series circuit, the loading coil comprising in actual practice a circular hard rubber or bakelite form provided with plugs or binding posts so that the same could be readily plugged in or connected to a receiving set between the antenna connection of the set and the upper terminal of the primary winding of the coupling transformer.

Such an arrangement is shown in the right-hand figure.

28. In lieu of the loading coil method of increasing the resonant wave length to which the antenna circuit will respond, the same basic result may be accomplished by placing the adjustable tuning condenser in a shunt circuit around the primary of the coupling transformer. Such a parallel connection of the condenser as shown in the left-hand figure functions to decrease the natural periodicity of the antenna circuit below what it would be in the absence of the condenser, and thereby enables the primary circuit to be tuned to the relatively longer wave lengths.

29. For any given receiving installation in which the electrical constants of the antenna and the receiving set are known, the basic advantage of receivers constructed to utilize the shunt condenser connection may be ascertained in money value by calculating the size and cost of the loading coil required in the alternative series circuit to receive a signal of the same wave length. Such a calculation involves primarily the number of turns of wire necessary to provide the additional inductance. From this figure the length and cost of the wire are ascertainable, to which may be added the cost of the hard rubber coil form, together with the necessary labor cost and a profit. The total cost of the loading coil will therefore represent the monetary advantage due to the use of the shunt condenser connection.

[fol. 120] 30. Besides the monetary advantage in the receivers constructed to utilize the shunt condenser connection, as indicated in the previous finding, this type of connection as compared with the series connection, plus the loading coil, results in other advantages, as follows:

(a) The set is more compact, requires less room, and weighs less;

(b) At the longer wave lengths the sensitivity and selectivity are both greater.

This latter advantage is due to the fact that the use of a loading coil introduces additional resistance into the antenna circuit, and also an effect known as distributed capacity in which the adjacent turns on the loading coil tend to act as small capacities. The resistance tends to weaken the already feeble currents induced in the receiving antenna, and the distributed capacity effect tends to dissipate them.

These advantages, while somewhat intangible, are nevertheless of real benefit.

31. During the Marconi accounting period, especially in 1917-1919, the reception of messages, press and weather reports, enemy propaganda, etc., on the longer wave lengths was of great importance to the United States, particularly in the Naval service. As early as 1913, time signals and weather reports were regularly transmitted on the wave length of 2,500 meters. By 1915, much longer wave lengths were in use, wave lengths up to 15,200 meters having been regularly assigned. From this time on, the entire Primary System of Naval communications was carried on on wave lengths above 3,000 meters, and the regular communication wave length for the Secondary System was 952 meters. In 1919 and prior thereto practically all long-distance radio communication, such as transoceanic, transcontinental, etc., was carried on on wave lengths above about 10,000 meters. Plaintiff's Exhibit 484, which is by reference made a part of this finding, shows fifty-seven (57) orders issued by the Navy Department in 1916 for loading coils, each for a different station, such loading coils being for the purpose of increasing the wave-length range of existing sets.

32. For convenience of consideration, the receiving sets acquired and used by the Government during the Marconi accounting period and so constructed as to utilize the in- [fol. 121] vention set forth in claim 16 of the Marconi patent, are segregated into groups, as shown in the accompanying tabulation. The following tabulation carries in the last column the size of a loading coil (expressed in millihenries of inductance) which would be necessary for use as an alternative to the parallel condenser connection.

RECEIVERS WITH PERMANENTLY CONNECTED PARALLEL CONDENSER

Item No.	Contract No.	Approximate year acquired	Number of receivers	Type of receivers	Additional coil size
Pickard		1918	4	Otter Cliffs	74 3
W. Spec. App. Co.		1918	5	..do	74 3

RECEIVERS WITHIN GROUP I

Item No.	Contract No.	Approximate year acquired	Number of receivers	Type of receivers	Additional coil size
15 16	35659	1919	266	SE-950	4 73
J. O.	12-Z-2252	1919	25	SE-950	4 73
17	36124	1919	288	SE-1012	1 13
J. O.	12-Z-2309	1919	25	SE-1012	1 13
21-22	40459	1919	246	SE-1012A	1 13

RECEIVERS WITHIN GROUP II

(a) TELEFUNKEN RECEIVERS

Item No.	Contract No.	Approximate year acquired	Number of receivers	Type of receivers	Additional coil size
A-51		1910	2	(Telef.)	5 85
38	211	1911	2	GAH, KOHF	3 33
40	13549	1911	1	GAH	.5
A-60	444	1911	3	GAH or KOHF	3 33
B-31	455	1911	4	GEK-2	5 85
B-31	455	1911	3	(Telef.)	3 33
28	458	1912	2	GAH	.37
29	144	1912	3	GEK-2	4 2
39	12899	1912	38	GAH, KOHF	6 06
42	15232	1912	8	GAH, GEK-2.	7 75
42	15232	1912	4	..do	.3
43	15294	1912	6	GAH	3 33
44	101	1912	2	GEK-2	2 34
45	16408	1912	1	..do	1 0
45	16408	1912	1	..do	.3
45	16408	1912	1	..do	2 34
46	14747	1912	15	E-5	3 33
47	256	1912	1	(Telef.)	4 2
A-76	538	1912	2	E-4	3 33
A-77	486	1912	1	(Telef.)	3 33
B-32	468	1912	1	GAH or KOHF	3 33
B-33	474	1912	1	..do	3 33
30	123	1913	6	E-4, E-5	2 34
A-78	510	1913	4	(Telef.)	3 33
A-79	527	1913	1	..do	3 33
34	608SC	1914	1	E-4	7 5

(b) FEDERAL RECEIVERS

Item No.	Contract No.	Approximate year acquired	Number of receivers	Type of receivers	Additional coil size
(Arlington)		1912	1	Federal	3 4
Plf. Ex. 407		1913	1	..do	6 5
32	1948B	1914	1	..do	10 3
48	269	1914	3	..do	3 9
49	55	1915	2	..do	6 5
50	350	1915	2	..do	6 5

[fol. 122]

(c) MISCELLANEOUS

Item No.	Contract No.	Approximate year acquired	Number of receivers	Type of receivers	Additional coil size
\-27	562	1913	1	IP-76 (1913)	7
35	231	1914	4	Spec. 16-R-1	18 6
A-35	19882	1914	10	IP-76 (1914)	10 5
A-35	19882	1914	13	IP-76 (1912)	4
36	225	1915	5	Spec. 16-R-1	18 6
41	20437	1915	4	..do	18 6
A-7	157	1917	3	..do	18 6
A-12	186	1917	1	..do	18 6
Ericson		1917	1		2 27
Montcalm		1919	10		85 4
Nat. Elec. Sup. Co.		1919	2	Remodeled	

RECEIVERS WITH PERMANENTLY CONNECTED PARALLEL CONDENSER—Continued

RECEIVERS WITHIN GROUP IIIA

Item No.	Contract No.	Approximate year acquired	Number of receivers	Type of receivers	Additional coil size
J. O.	12-Z-23629	1917	1	SE-143	16
6	31414	1918	247	do	16
10	33077	1918	150	do	16
12	1064	1918	30	SE-952	2
14	35479	1918	306	SE-143	16
18	3385	1918	27	SE-899	10
19	35979	1918	50	SE-998	7
5	31413	1919	112	SE-143	16
8 (part)	375	1919	27	SE-899	10
9	33064	1919	200	SE-143	16
13	35478	1919	200	SE-899	10
26	43723	1919	301	do	10
J. O.	12-Z-24328	1919	183	SE-143	16

RECEIVERS WITHIN GROUP IIIB

Item No.	Contract No.	Approximate year acquired	Number of receivers	Type of receivers	Additional coil size
7	853	1917	100	CN-239	36
A-47	28838	1917	1	CN-208	6 25
A-47	28838	1917	1	CN-239	36
3 (part)	28735	1918	27	CN-208	6 25
3 (part)	28735	1918	40	CN-239	36
4	95	1918	200	CN-240	36
11	939	1918	1	CN-208	6 25
J. O.	12-Z-1857	1918	60	SE-95	130
8 (part)	375	1919	73	CN-240	36
20	38271	1919	300	SE-1220	30
24	42615	1919	59	do	30
Pl. Exh. 432		1919	201	do	30
Pl. Exh. 432		1919	13	SE-95A	130
A-48	34429	1919	60	SE-1220	30

NOTE.—The item numbers given in the first column of the table identify the various items set forth on the contracts and abstracts listed in Finding 7 and made a part thereof.

Where J. O. occurs under an item number, this indicates manufacture by the Government under a job order instead of purchase by contract.

33. A more detailed explanation of certain of the items included in the above tabulation is as follows:

(*Arlington Federal receiver*).—In the latter part of 1912 a Federal Telegraph Company radio receiver was acquired by the Navy Department for use at the Arlington Navy Radio Station, this receiver being used in official Navy work, and the set had a switch providing for the parallel connection of the antenna tuning condenser.

[fol. 123] (*Item A-27*).—This item refers to one receiver covered by a contract with the Telefunken Company dated January 29, 1913, for installation on the U. S. Army Transport "*Liscum*." While the abstract of this contract shows no record of payment in the contract file, plaintiff's Ex-

hibit 428, item 9 has reference to an official notice referring to this contract and indicating that the set of which this receiver was a portion was inspected and accepted.

(*Item A–47*).—This item refers to a contract for one long-wave receiver and one short-wave receiver. By cross-reference to the contract abstracted under Item 3, these sets specified are one type CN-208 short-wave receiver and one type CN–239 long-wave receiver. These receivers were paid for by a check dated June 28, 1917.

(*Item A–48.*)—This item relates to contract No. 34429 of January 5, 1918, which as finally amended required delivery, among other things, of 60 SE–1220 receivers on a cost-plus-10 percent basis. The date of delivery of the receivers does not appear but the abstract of the contract file (plaintiff's Exhibit 408–A) indicates that the work under this contract had been completed by the contractor prior to November 20, 1919, the close of the accounting period. Out of thirteen public bills listed in the contract files only two are dated subsequent to November 20, 1919, and both of these show no payments by the defendant for "Factory overhead expense" or for "Gen. and Adm. expense" for any date later than October 31, 1919. A release dated February 16, 1920, shows full performance of the contract by the contractor and full payment by the defendant.

34. Certain apparatus designated as follows has been omitted from the tabulation given in Finding 32 as not properly coming within the accounting:

(*Item 1*).—This item relates to a contract which called for the rebuilding of a 2-kw. Telefunken wagon set. The abstract of the contract contains the statement "No evidence of receiver being supplied in rebuilding of this set." Plaintiff's Exhibit 428, abstract of papers of the U. S. Signal Corps, contains reference to a letter showing receipt and acceptance (Item 11). The wagon set as accepted contained one receiving set. There is no proof that the receiver itself [fol. 124] was rebuilt or that, if rebuilt, it embodied the parallel condenser connection.

(*Items 15–16*).—The abstract of this contract and supplemental contract shows 301 SE–950 receivers called for and the abstract, under "remarks," contains the statement "37 receivers with payment therefor not accounted for."

(*Item 17*).—This item relates to a contract calling for 300 type SE–1012 receivers. The remarks under the abstract of this contract state "Only 288 receivers of the 300 called for are accounted for in the contract file."

(*Item 50*).—This item is already referred to in detail in connection with the Lodge patent (see Finding 12). This item called for 5 sets complete with receivers and contained no proof of delivery of three of the sets.

(*Item A–35*).—This item covers a contract calling for thirty radio receivers at a total contract price of $9,380. The contract file shows delivery of and payment during the Lodge accounting period for twenty-three of the receivers. There is no proof of delivery of or payment for the remaining seven receivers, the contract price for which was $1,918.

(*Item 6*).—The abstract of this item relates to a contract calling for 600 short-wave receivers. The abstract under remarks contains the statement "only 247 sets delivered on this contract."

(*Item 14*).—This item relates to a contract dated March 7, 1918, and calling for 400 receivers type SE–143. The public bills and vouchers listed in the contract show payment for only 306 receivers and there is no proof of delivery of or payment for the remaining 94 receivers.

(*Item 5*).—This item of a contract under date of August 4, 1919, called for 250 short-wave receivers. The remarks in the abstract contain the following statement: "Only 112 receivers made."

Receivers with permanently connected parallel condenser

35. The nine receivers listed in this group in the tabulation given in Finding 32 were installed at the Otter Cliffs Station on Mount Desert, Maine. This was a radio station constructed by a Mr. Alessandro Fabri some time in the [fol. 125] summer of 1917, which station was turned over to the Navy Department later in that year. This station was subsequently manned by a Navy staff and because of its geographical position and relative freedom from static, was used extensively by the Navy to receive from the high-power long-wave European stations.

The station was originally equipped with five Wireless Specialty Apparatus Company receivers, and Professor Pickard while stationed at the Otter Cliffs Station constructed at least four other receiving sets from Navy material. All of the nine sets had the tuning condenser of the open circuit permanently connected in parallel with the primary winding of the coupling transformer and all of these sets were utilized in the regular reception of messages by the Navy Department.

Receivers within Group I

36. The receiving sets tabulated under Group I possessed a control device for progressively adding antenna inductance to the open circuit as a knob was turned. By means of a cam arrangement, when the last positions of the knob were reached, the open circuit was altered from a series condenser connection to a connection in which the tuning condenser was in parallel with the load coil and primary coil of the open circuit.

Receivers within Group II

37. This group of receivers and tuners was provided with a variable tuning condenser in the antenna circuit, and had a switch by means of which the operator of the receiver could at will connect the condenser either in series or in parallel with the inductance coils of the open circuit, including the primary winding of the coupling transformer.

The item identified as "Ericson" near the end of the tabulation of Group II was a receiver installed at the United States Naval Reserve Force Radio Station at Bath, Maine, and had a series parallel switch installed on the exterior of the cabinet at the left-hand end.

The ten receivers listed in this group under the item "Montcalm" were located and were used at the United [fol. 126] States Naval Radio Station at the American Legation in Peking. The station was located within the legation grounds. The sets were built at the station, the condensers being obtained from stock at the Cavite Navy Yard, the coil forms made up by local labor, and the sets put together and assembled by Marines.

Receivers within Group IIIA

38. The receivers and receiving tuners listed within Group IIIA were designed by or under the supervision of

Navy engineers. These sets were intentionally designed to enable the operator to employ either (a) the series condenser connection alone, (b) the series connection with a load coil, or (c) the parallel connection of the antenna tuning condenser.

Several constructional features of these sets contributed to such a universal use, among which were the location of the primary tuning condenser between the antenna connection and the primary of the coupling coil instead of the customary location of the condenser between the ground and the lower end of the primary winding where stray capacity effects are a minimum; bringing out the necessary leads and wires to binding posts located on the face or panel of the receiver so that modification of the connections could be made without any alteration of connections within the receiver cabinet, and to receive a longer wave-length range than the wave-length range of the primary circuit with a series condenser connection in some instances by provision for loading coils in the secondary circuit.

The binding posts on the panel were suitably identified by engraved legends and the operators' instruction books accompanying the sets made specific reference to the parallel condenser connection, the purposes of it, and how to obtain it by suitable connections on the face of the panel. The following is quoted from the instruction book for the type SE–143 receiver, plaintiff's Exhibit 413B, which is made a part hereof by reference, this quotation being given by way of example:

> The range of the primary of this receiver is 250 to 3,100 meters. The range of the tuned secondary is 250 to 6,800 meters. The primary may be increased from its nominal range of 3,100 meters to over 7,000 meters on any antenna [fol. 127] by connecting as shown in figure #1.
>
> This places the primary variable condenser in parallel with the primary inductance. This combination is very efficient on waves longer than 3,000 meters; on short waves, it is not as efficient as the series capacity.
>
> The change-over from shunt to series connection can be made quickly by using a double pole double throw switch as shown in figure #2.

The figures 1 and 2 referred to in the above-quoted portion are circuit diagrams visually instructing the operator what connections to make to the panel binding posts.

All of the sets in Group IIIA were accompanied by instruction books which described to the operator of the set the proper connection to the binding posts by means of which the parallel primary condenser connection could be obtained.

Receivers within Group IIIB

39. The constructional features of the receivers in this group are identical to those listed in Group IIIA with respect to being designed so that the operator could make the necessary panel connections to employ either (a) the series condenser connection alone, (b) the series connection with a load coil, or (c) the parallel connection of the antenna tuning condenser. The instruction books accompanying the receivers in this group did not indicate to the operators what connection should be made to the binding posts on the panels in order to obtain the parallel condenser connection.

There is evidence that Navy wireless operators familiar with the radio sets had knowledge of the advantages of the parallel condenser connection and utilized such circuit in the reception of official Navy communications and in accordance with orders of their superior officers in connection with the use of Group IIIB as well as Group IIIA receivers.

40. Calculation of the cost of the alternative loading coils involves a number of fixed material and labor costs, irrespective of the size or value of the loading coil, these fixed charges being set out specifically in Findings 42 and 43.

Such fixed costs make it possible to use an average load coil value for a group of receiving sets and thus simplify the calculation.

[fol. 128] The following table gives an average loading coil value in millihenries for the groups of sets tabulated, and in addition segregates the receivers acquired by contract from those manufactured by the Government or otherwise acquired:

Period	Group	Acquired by contract	Acquired otherwise	Total	Average load coil value
1910 1911	II	15	..	15	4 15
1912 1913	II	101	..	101	4 49
1914 1915	II	45	..	45	10 13
1917	Receivers permanently connected	5	4	9	74 3
1918	II	5	..	5	15 33
	IIIA	810	1	811	14 34
	IIIB	370	60	430	47 11
1919	I	800	50	850	2 36
	II	2	10	12	71 27
	IIIA	840	183	1,023	12 90
	IIIB	693	13	706	32 46
Total		3,686	321	4,007	Ave. 18 11

41. During the accounting period two types of loading coils were used, these types being designated as the "bank-wound" and "layer-wound" loading coil. The bank-wound coil was electrically more efficient in that the type of winding reduced the distributed capacity, and therefore reduced losses in the circuits. Bank winding required a particular art or skill, and there is no satisfactory evidence upon which to base the labor cost of such winding during the accounting period.

The layer-wound coils were wound on a hard-rubber spool, the second layer being wound upon a completed first layer, the third layer upon the second layer, etc. The cost estimate of the loading coils as used in the present case for a determination of just and reasonable compensation is based upon the layer-wound type of loading coil. This type of coil is not so efficient electrically as the bank-wound coil, due to distributed capacity effects. Labor costs in connection with the winding of the layer-wound type of coil are less than the labor costs of winding the bank-wound coils, and the cost figures for loading coils, given in the following findings, are for this reason conservative.

42. The cost of the layer-wound coils is divided into material and labor. The following tabulation gives the material [fol. 129] cost for the eleven sizes of loading coils set forth in Finding 40, *supra*. The cost of material for the coil form and hardware is the same for all sizes of the coil, being $1.77. The feet of wire for the different coil values are indicated on a graph (Commissioner's Exhibit CE-2, which is by reference made a part of this finding). This graph indicates the number of feet of wire

necessary for any given value in millihenries of the loading coil.

The wire which was used during the accounting period for the manufacture of loading coils is known as Litzendraht wire, and cost two cents per foot during the accounting period.

Load coil value (millihenries)	Material costs: Cost of call form	Feet of wire	Cost of wire at 2 cents per foot	Total material cost
4 15	$1 77	180	$3 60	$5 37
4 49	1 77	190	3 80	5 57
10 10	1 77	310	6 20	7 97
74 3	1 77	1,025	20 50	22 27
15 33	1 77	385	7 70	9 47
14 34	1 77	375	7 50	9 27
47 11	1 77	780	15 60	17 37
2 36	1 77	128	2 56	4 33
71 27	1 77	1,000	20 00	21 77
12 90	1 77	355	7 10	8 87
32 46	1 77	625	12 50	14 27

43. The cost of direct labor of the type employed in winding, assembling, and making radio coils during the accounting period was eighty-one cents ($0.81) per hour. The length of time in minutes required to wind load coils of various sizes is shown on a graph (Commissioner's Exhibit 7, which is by reference made a part of this finding).

The following tabulation, which includes an indirect labor charge of 20 percent, is indicative of the labor costs involved in the various sizes of coils indicated. The fixed labor, as given in minutes, includes an average of seventy-five minutes for machining the coil form, and the remaining time of thirty-five minutes is inclusive of such fixed operations as getting stock, drilling for leads, mounting binding posts, placing form on arbor, tightening nut, setting turn counter, starting winding, bringing out finishing lead, clean- [fol. 130] ing and soldering leads to binding posts, removing coil and counter, baking and dipping, and testing.

Load coil value	Fixed labor in minutes	Winding time in minutes	Total time in minutes	Direct labor cost at $0.81 per hour	Indirect labor—20 percent of direct	Total labor cost
4 15	110	9	119	$1 61	0 32	$1 93
4 49	110	9	119	1 61	.32	1 93
10 10	110	13	123	1 66	33	1 99
74 3	110	29	139	1 88	.38	2 26
15 33	110	15	125	1 69	34	2 03
14 34	110	15	125	1 69	34	2 03
47 11	110	24	134	1 81	36	2 17
2 36	110	7	117	1 58	32	1 90
71 27	110	29	139	1 88	38	2 26
12 90	110	14	124	1 67	33	2 00
32 46	110	21	131	1 77	35	2 12

44. The following tabulation is indicative of the cost (material plus labor) of the eleven sizes of load coils given in the previous tabulations, and also contains in the last column what the approximate cost of the load coils would be if sold to the Government by a contractor, this column adding 20 percent profit to the cost of the coils:

Load coil value (millihenries)	Cost	Cost plus 20 percent profit	Load coil value (millihenries)	Cost	Cost plus 20 percent profit
4 15	$7 30	$8 76	47 11	$19 54	$23 44
4 49	7 50	9 00	2 36	6 23	7 48
10 10	9 96	11 95	71 27	24 03	28 83
74 3	24 53	29 43	12 90	10 87	13 04
15 33	11 50	13 80	32 46	16 39	19 67
14 34	11 30	13 56			

45. The following tabulation sets forth the total cost estimate of the loading coils, this being indicated both by period and group:

[fol. 131]

Period	Group	Acquired by contract	Acquired otherwise	Cost of load coil	Total value load coils	By periods	Other advantages $2.50 per set	By periods	Total
1910, 1911	II	15	...	$8.76	$131.40	$131.40	$37.50	$37.50	$168.90
1912, 1913	II	101	...	9.00	909.00	909.00	252.50	252.50	1,161.50
1914, 1915	II	45	...	11.95	537.75	537.75	112.50	112.50	650.25
1917, 1918	Receivers permanently connected	5	...	29.43	147.15	...	12.50	...	...
	do	...	4	24.53	98.12	...	10.00	...	...
	II	5	...	13.80	69.00	...	12.50	...	...
	IIIA	810	...	13.56	10,983.60	...	2,025.00	...	...
	IIIA	...	1	11.30	11.30	...	2.50	...	...
	IIIB	370	...	23.44	8,672.80	...	925.00	...	...
	IIIB	...	60	19.54	1,172.40	...	150.00	...	...
						21,154.37		3,137.50	24,291.87
1919	I	800	...	7.48	5,984.00	...	2,000.00	...	...
	I	...	50	6.23	311.50	...	125.00	...	...
	II	2	...	28.83	57.66	...	5.00	...	...
	II	...	10	24.03	240.30	...	25.00	...	...
	IIIA	840	...	13.04	10,953.60	...	2,100.00	...	...
	IIIA	...	183	10.87	1,989.21	...	457.50	...	...
	IIIB	693	...	19.67	13,631.31	...	1,732.50	...	...
	IIIB	...	13	16.39	213.07	...	32.50	...	...
						33,380.65		6,477.50	39,858.15
						56,113.17	...	10,017.50	66,130.67

[fol. 132] 46. Other advantages in receivers constructed to utilize the shunt condenser connection, as compared to those utilizing loading coils, are set forth in Finding 30. For convenience, these advantages are reiterated:

(a) The set is more compact, requires less room, and weighs less;

(b) At the longer wave lengths the sensitivity and selectivity are both greater.

These advantages are of maximum benefit in sets constructed to receive the longer wave lengths and are of little or no value in the short-wave sets involving a load coil of only a few millihenries, with relatively few turns of wire. Referring to the average load coil value in the tabulation given in Finding 40, the maximum value is 74.3 millihenries and the minimum value is 2.36 millihenries. A fair and reasonable value of the advantages expressed in Finding 30 would be $10 per set for the long wave-length sets of 74.3 millihenries, and there would be no monetary value for a receiver which requires no load coil. The average load coil value for the 4,007 sets is 18.11 millihenries. Based on this average, the monetary value for this advantage per set for all the sets is approximately $2.50. This is included in the above tabulation as therein indicated.

47. A reasonable and entire compensation to plaintiff for use by the United States during the Marconi accounting period of the invention defined by claim 16 of the Marconi patent No. 763,772, is 65 percent of $66,130.67, or the sum of $42,984.93, together with interest at 5 percent per annum on the following sums from the respective dates given to the date of payment of the judgment, not as interest but as part of the entire compensation: $109.78 from December 31, 1911; $754.97 from December 31, 1913; $422.66 from December 31, 1915; $15,789.72 from December 31, 1918, and $25,907.80 from November 20, 1919.

Conclusion of Law

Upon the foregoing special findings of fact, which are made a part of the judgment herein, the court decides as a conclusion of law that plaintiff is entitled to recover the sum of $77,812.63, with interest at 5 percent per annum, not as interest but as part of just compensation.

[fol. 133] It is therefore adjudged and ordered that the plaintiff recover of and from the United States the sum of seventy-seven thousand, eight hundred twelve dollars and sixty-three cents ($77,812.63), with an additional amount measured by interest at the rate of 5 percent per annum on the following sums from the dates specified until paid: $34,827.70 from August 16, 1915; $109.78 from December 31, 1911; $754.97 from December 31, 1913; $422.66 from December 31, 1915; $15,789.72 from December 31, 1918, and $25,907.80 from November 20, 1919.

Opinion

Whaley, *Chief Justice*, delivered the opinion of the court:

This is a patent case now before the court for the determination of the reasonable and entire compensation to which plaintiff is entitled for the appropriation of the right to use certain inventions covered by United States letters patent to Lodge 609,154, and to Marconi 763,772.

The court on November 4, 1935, filed findings of fact with an opinion (81 C. Cls. 671), holding that the Lodge patent was valid as to claims 1, 2, and 5 and had been infringed, and that claim 16 of the Marconi patent was valid and had been infringed. This case was remanded to a commissioner of this court in accordance with the stipulation of the parties that the issue of reasonable compensation be postponed until the determination by the court of the issues of validity and infringement of the various patents in suit.

The record shows notice of the closing of proof on December 20, 1940, under the order of remand. The commissioner's report was filed June 9, 1941, and both parties have filed numerous exceptions thereto. Inasmuch as the periods for recovery differ with respect to the patents involved, and as the theory upon which reasonable compensation has been found also differs, these patents will be separately discussed.

Lodge Patent 609,154

The Lodge accounting period extends from March 8, 1913, when plaintiff first gave the notice of infringement to [fol. 134] defendant, to August 16, 1915, which is the date of expiration of the patent.

The issues presented by the parties in their exceptions to the commissioner's report with respect to this patent may

well be termed the customary or stock issues raised in a patent accounting. They may be briefly summarized as follows and will be considered in this order:

(1) The place of the Lodge patent in the radio art, i. e., whether it is commercially basic in character or whether it is merely an improvement;

(2) Whether the 10% royalty found by the commissioner is correct, plaintiff urging that this percentage is too low and defendant urging that it is too high; and

(3) Whether certain wireless apparatus should be included or excluded from the accounting or, more specifically stated (a) whether the Lodge patent relates to radio receivers sold separately; (b) whether certain spare parts of wireless appartus should be included or excluded from the accounting, and (c) the question of the burden of proof relative to the acquirement of certain items of radio apparatus.

The status of a patent in the art with which it is associated is of importance in determining the base which is to be used in an accounting. The reason for this is succinctly set forth in *Garretson* v. *Clark*, 111 U. S. 120, in which it is stated:

When a patent is for an improvement, and not for an entirely new machine or contrivance, the patentee must show in what particulars his improvement has added to the usefulness of the machine or contrivance. He must separate its results distinctly from those of the other parts, so that the benefits derived from it may be distinctly seen and appreciated. The rule on this head is aptly stated by Mr. Justice Blatchford in the court below: "The patentee," he says, "must in every case give evidence tending to separate or apportion the defendant's profits and the patentee's damages between the patented feature and the unpatented features, and such evidence must be reliable and tangible, and not conjectural or speculative; *or he must show*, by equally reliable and satisfactory evidence, *that the profits and damages are to be calculated on the whole machine, for the reason that the entire value of the whole machine, as a* [fol. 135] *marketable article, is properly and legally attributable to the patented feature.*" [Italics ours.]

From a consideration of subsequent cases, the application of this rule relates more directly to an accounting

based upon profits rather than the type of accounting which is based on reasonable royalty and which has been followed in the present case with reference to the Lodge patent. This becomes apparent if we consider a theoretical instance, in which the profits, due to the patented portion of a machine, have on apportionment been found to be 25 percent of the total profits on the machine, the remaining 75 percent being due to extraneous elements or elements patented by others. In such a case plaintiff would be entitled only to the profits on the features or elements covered by his patent. If, however, the recovery of compensation in the same instance were measured by a reasonable royalty, such a procedure would take into consideration both the nature of the patented invention and its relation to the entire machine as a whole. Thus, in applying a reasonable royalty rule to the same situation just outlined, the differential between the patented and unpatented features of the machine would be taken into account by scaling down the percentage of royalty accordingly. It would make no difference in the ultimate compensation to plaintiff if the reasonable royalty were fixed at 5 percent of the selling price of the complete machine rather than 20 percent of one quarter of the sales price of the machine.

The Lodge patent relates to the selective tuning or syntonizing of the antenna circuits of a transmitting station with a receiving station. Plaintiff urges that the invention is fundamental or basic in character and that the entire market value rule be followed. Defendant urges that apportionment be made and that certain wireless apparatus not directly involved in accomplishing the tuning, and exemplified by arc transmitters, detectors, and amplifiers, be omitted from the base from which compensation is measured.

The three claims of the Lodge patent which have been held valid and infringed are quoted in Finding 5 accompanying this opinion, and the basic position of the Lodge patent in the art is defined in the following quotation from [fol. 136] the former findings of this court in its consideration of validity and infringement, in which it is stated that:

Marconi in his patent #586,193 apparently did not appreciate the desirability of tuning the primary oscillating circuit by the use of an inductance coil, and did not contem-

plate varying the effective tuning of the receiver to one of several transmitters. * * *

No one prior to Lodge appreciated the desirability of tuning the oscillating circuits of both the transmitter and receiver for the purpose intended and in the manner performed by him.

The ability to *selectively* and *adjustably* tune the antenna circuits of any receiving station to any desired transmitting station, or vice versa, was of fundamental importance to radio communication, and this is so obvious that it requires no lengthy explanation.

One of plaintiff's expert witnesses, Mr. Pickard, who has been engaged continuously in the field of radio communication from 1898 to the present time and during the major part of that time acted as a consulting engineer and was engaged in research and design work, testified with respect to the commercial and practical value of the Lodge invention as follows:

Q. 31. What was accomplished by the insertion of the lumped inductance in the antenna and what was its effect upon the development of the radio art and the development of radio communications?

A. What was accomplished by the lumped inductance was simply to permit any number of stations to operate within a given area, and so far as its effect upon the development of the art was concerned, it literally permitted the development of the radio art, which in the absence of such a means as the Lodge invention, would have been merely an interesting experiment.

* * * * * * *

Q. 37. Looking at the matter from the point of view of commercial utility will you in sum, so to speak, compare the utility of radio without the Lodge invention to its utility with it?

A. Without the Lodge invention radio had no practical utility. With it it had a very practical utility.

[fol. 137] One of defendant's expert witnesses, Commander Lavender, who had experience in radio communication work beginning in 1913, testified as follows in his cross-examination:

X Q. 240. Could you have built, in 1913, 1914, and 1915 a practical receiver which did not embody the Lodge invention?

A. No.

* * * * * * *

X Q. 248. And from your experience as one familiar with radio do you believe that—and I am asking for your own testimony—the Bureau of Engineering would have said that they could have gotten along without the Lodge invention?

A. I do not believe that they could have gotten along without it.

We are of the opinion that while the Lodge invention dealt primarily with tuning, the invention was of such paramount importance that it substantially created the value of the component parts utilized in the radio transmitters and receivers purchased or acquired by the United States during the accounting period, and that it therefore falls within the entire market value rule. The complete cost of the transmitting and receiving sets should be used as the base in the application of a reasonable royalty.

The commissioner found a fair and reasonable royalty on the Lodge patent during the accounting period to be 10 per cent of the selling price or market value of the radio transmitters, receivers and sets, and such apparatus as is dependent upon the invention thus defined for its utility. Defendant urges that the figure should be cut to 5 per cent and plaintiff asks that it be increased to 15 per cent. These requested values are based largely upon the opinion testimony of expert witnesses presented by both plaintiff and defendant.

The courts look with favor toward the establishment of a reasonable royalty as a measure of compensation in a patent accounting. This method usually obviates many difficulties connected with the establishing of such items as costs, profits, apportionments, expense of doing business, etc., all [fol. 138] of which are matters frequently difficult to ascertain in a legal procedure.

If the plaintiff has already established a royalty by a license or licenses, he has himself fixed the average of his compensation, and if this has been established prior to the

infringement, the task of the court then becomes easy. If such is not the case, a court will next take into consideration any act or acts of the plaintiff in connection with third parties which would tend to indicate an accepted monetary value for the use of the plaintiff's invention. Contracts made with others even during the infringing period or subsequent thereto may be considered provided there is no room for suspecting collusion and the circumstances of the contracts would seem to repel any doubt of their good faith and negative the question of whether they had been entered into for the precise purpose of establishing an excessive royalty.

In the *Cincinnati Car Company* v. *New York Rapid Transit Corporation*, 66 Fed. (2d) 592, 595, Judge Learned Hand said:

> The plaintiff had made five settlements, four of them after infringement, and upon all of its three patents, one of which we declared uninfringed. * * * Though the payments were not established royalties, we need not disregard them, any more than the master did. It is true that they were settlements for infringements, but both parties may have been influenced by a wish to be done with litigation; that consideration is a sword with two edges.

See also *Meurer Steel Barrel Co.* v. *The United States*, 85 C. Cls. 554, 562 (certiorari denied, 302 U. S. 754).

Finally, in the order of consideration is the testimony of expert witnesses, those more or less familiar with the establishing of royalty rates in any particular art. We place this last not because of any lack of credibility or integrity of witnesses who testify with respect to a reasonable royalty but more because the opinion of any one witness is based upon his own individual approach to the art or industry concerned, and would take into consideration numerous factors which a second witness, equally honest, might entirely disregard. As each party will present to the court only [fol. 139] those witnesses whose opinions in general favor their cause, such evidence, which is itself speculative, is sometimes of small help.

In Finding 13 we have set forth in detail four nonexclusive licenses which plaintiff granted to others during the Lodge accounting period to manufacture and sell wireless apparatus embodying the inventions of both the Lodge

patent and Marconi patent 763,772. These licenses all indicate a minimum royalty under the two patents of 20 per cent of the listed catalog or selling price, and the licenses under date of October 15, 1914, to the National Electric Signaling Company, and under date of July 26, 1915, to the Clapp-Eastham Company, both provide for a royalty of 20 per cent on all sets sold to the United States.

When the Lodge patent expired on August 16, 1915, the plaintiff granted numerous other nonexclusive licenses under the Marconi patent alone. These included a new license to the Clapp-Eastham Company. The license fee or royalty fee provided for in these license agreements subsequent to the expiration of the Lodge patent was 10 per cent of the lowest selling price. Thus, these various contract agreements with third parties seem to indicate rather conclusively that the plaintiff and its licensees had in mind at that time an equal allocation of the 20 per cent royalty between the Lodge and the Marconi patents, and that 10 per cent is a just and reasonable royalty for the use of the Lodge patent alone during the accounting period. We think the commissioner is correct in his finding of 10 per cent as a reasonable royalty for this patent.

We next consider the issue of whether certain apparatus should be included in or excluded from the accounting base to which the royalty is applied. The first group of apparatus to consider comprises approximately 200 wireless receivers contained in eleven different contract items. These are receivers which were sold separately to the Government and not in conjunction with transmitting apparatus or complete station equipment.

Defendant's argument is that the claims of the Lodge patent which have been held valid and infringed by the court are directed to the capacity and lumped inductance, [fol. 140] and we quote from defendant's brief, "in the antenna at the local station and at a distant station." Insofar as we are able to follow defendant's argument, it assumes that the Lodge claims are directed to a system of wireless communication involving a transmitter and a receiver tuned thereto, and that where a transmitting set and a receiving set have been sold to the Government as a combination it is proper that they should come within the accounting, but where a receiver has been sold separately it represents an incomplete combination or a portion only of

the patented system, and therefore does not come within the accounting.

The language of the Lodge patent itself negatives this assumption of a system comprising a single transmitter cooperating with but one receiver, and instead contemplates a transmitter sending to a plurality of receivers. See lines 8-17, page 1 of the specifications, reading as follows:

> The object of my invention is to enable an operator, by means of what is now known as "Hertzian-wave telegraphy," to transmit messages across space *to any one or more of a number of different individuals in various localities, each of whom is provided with a suitably arranged receiver*, and to effect the ancillary improvements the nature of which are hereinafter more particularly described and claimed. [Italics ours.]

Defendant further argues that inasmuch as it is entitled to use certain systems involving both transmitters and receivers using the Lodge invention, but acquired *prior* to the Lodge accounting period, it has an implied license to continue the use of such systems and therefore has a right to purchase new receivers for use with the old transmitters, or, expressed in other words, defendant has a right to repair its prior acquired systems by the substitution of a new receiver for and old or worn-out receiver.

Defendant's argument is based on a false premise. The claims in suit of the Lodge patent are not limited to a system involving a combination of a transmitter with a receiver. In this court's former special findings of fact we specifically found (Finding XXVII) that:

> The Lodge patent relates to the provision of a self-inductance coil between a pair of capacity areas in an oscillating circuit of *either or both a sending or receiving set* for Hertzian wave telegraphy. [Italics ours.]

[fol. 141] Moreover, claim 5 is directed to the antenna circuit of either a transmitter or receiver, the circuit including a variable acting self-inductance serving to syntonize such antenna circuit to any other such antenna circuit.

With respect to the radio equipment acquired prior to the accounting period, defendant undoubtedly has a right, under the patent law as interpreted by the courts, to repair a system, but, on the contrary, it has no right to reconstruct

a system, and the installation of a new receiver would, in our opinion, amount to a reconstruction. (See our subsequent discussion in connection with repair parts.)

From the practical standpoint we can also see no assurance that any of the new receivers purchased separately would not be used whenever necessary to receive radio transmission from a transmitter acquired with the accounting period, and under the defendant's own theory of the Lodge invention being limited to a system, such use would then be an infringement.

We think that the receivers sold separately are properly within the accounting.

Certain extra parts are listed under a heading entitled "Value of parts" in the tabulation on pages 6 and 7 and are also individually itemized and set forth in greater detail in Finding 9. These parts, as taken from the various contracts, have a total value of \$56,448.82, and defendant urges that they comprise repair parts, and therefore should be omitted from the base figure to which any reasonable royalty by way of compensation is applied.

The general theory relating to spare parts is in substance that the user of a patented machine or device having once paid the patentee a royalty or other consideration for the right to its free use and enjoyment, is thereafter entitled to keep the machine or device in repair and to replace broken or worn-out unpatented parts of its mechanism with a corresponding part not necessarily purchased from the patentee. This principle is stated in Walker on Patents (6th Edition), Sec. 350:

> A purchaser may repair a patented machine which he has purchased, by replacing broken or worn-out unpatented parts, so long as the identity of the machine is not de- [fol. 142] stroyed, provided the machine itself is not an infringement. * * * And he may improve such a machine for his own peculiar use, by substituting for an unpatented part thereof, a corresponding part originally purchased, or not purchased, from the patentee. But no unauthorized person can lawfully engage in the business of reconstructing patented machines for their owners, by omissions and substitutions of parts, where those machines do not require any repair, but are thus changed with a view to their improvement.

Reference is also made to the opinion of the Supreme Court in *Leeds & Catlin* v. *Victor, etc. Company*, 213 U. S. 325, 336, in which the question of repair or replacement parts was considered in connection with the furnishing of additional phonograph records for a sound-production apparatus, as follows:

Can petitioner find justification under the right of repair and replacement as described in *Wilson* v. *Simpson*, 9 How. 109, and *Chaffee* v. *Boston Belting Co.*, 22 How. 217? The Court of Appeals, in passing on these cases, considered that there was no essential difference between the meaning of the words "repair" and "replacement." That they both meant restoration of worn-out parts. This distinction was recognized in *Wilson* v. *Simpson*, *supra*, where it is said that the language of the court in *Wilson's and Roussan's Case*, 4 How. 709, did not permit the assignee of a patent to make other machines or reconstruct them in gross upon the frame of machines which the assignee had in use, "but it does comprehend and permit the resupply of the effective ultimate tool of the invention, which is liable to be often worn out or to become inoperative for its intended effect, which the inventor contemplated would have to be frequently replaced anew, during the time that the machine as a whole might last." But there is no pretense in the case at bar of mending broken or worn-out records, or of repairing or replacing "the operative ultimate tool of the invention" which had deteriorated by use. The sales of petitioner as found by the courts below, and as established by the evidence, were not to furnish new records identical with those originally offered by the Victor Company, but, to use the language of Judge Lacombe in the Circuit Court, "more frequently in order to increase the repertory of tunes than as substituted for worn-out records."
[fol. 143] *The right of substitution or "resupply" of an element depends upon the same test. The license granted to a purchaser of a patented combination is to preserve its fitness for use so far as it may be affected by wear or breakage. Beyond this there is no license.* [Italics ours.]

See also *Miller Hatcheries* v. *Buckeye Incubator Co.*, 41 Fed. (2d) 619, for a complete discussion of this question.

The ultimate question is apparently one of "repair" versus "reconstruction" and its practical determination to

a large extent rests on the purpose for which the parts were intended.

Plaintiff's witness Clark testified with respect to the spare parts as follows:

Q. 1506. Did you personally have anything to do with the requirement for the delivery of spare parts in Navy contracts or in Navy specifications?

A. Yes, sir, I did.

Q. 1507. What, Mr. Clark?

A. I wrote the specifications which called in detail for such spares to be supplied.

Q. 1508. Will you please explain the reason for the purchase of spare parts for those transmitters?

A. Spare parts were replacement parts for such things as experience had shown might be destroyed during the normal use of the set—during the normal or military use of the set.

Q. 1509. Did the supply of spare parts have any relation to keeping the apparatus available for use at all times, no matter where the ship or station might be?

A. Yes. That is what the previous question meant—the previous answer meant.

Q. 1510. Will you amplify a little, please? In the absence of spare parts could continuous service be available at all times on a ship at sea, for example?

A. No. My previous answer meant that the spares were to insure continuous operation. That means that if any part were to break down due to any reason it would be replaced immediately by the spare and therefore the set would continue to be operative.

From this it is clear that the primary purpose of these spare parts was for "a repair" instead of "a reconstruction" of the sets. It is especially vital in military use to have sufficient replacement or repair parts on hand so as to maintain substantially continuous operation at all times.
[fol. 144] The question may be raised that the spare parts were furnished for infringing sets and not for radio equipment which the defendant had a right or license to use, and for this reason they do not fall within the spare parts rule and should be included in the accounting.

It is our view, however, that in the present method of awarding reasonable compensation based on a reasonable royalty and including interest from the time of acquirement of the radio equipment, defendant is placed in the position of a trustee ex maleficio, and as one who has paid a license fee at the time of acquirement and therefore is entitled to the use of the devices and also to their repair. In stating this we are not overlooking the possibility that some of these parts may have entered into the "reconstruction" of some of the sets that the defendant had previously acquired, or that even entire new sets had been built and some of these parts used. In the latter case, where satisfactory proof has been introduced, such sets have been included and form a portion of the base to which the royalty applies. In the former case we have no evidence before us which would enable any allocation of these parts to be made with reference to repairs versus reconstruction, and we must therefore depend on what is stated to be the primary purpose of these parts as set forth in the above-quoted testimony of the witness Clark.

The spare parts should be omitted from the base to which the reasonable royalty is applied.

We next come to the question of burden of proof with respect to about twelve items, this question being presented by plaintiff in that it urges that certain of these items which were omitted from the accounting should be included therein, and that certain other of these items should be given a larger market valuation than was given them by the commissioner.

A patent accounting frequently presents a problem of this nature. While it is the duty of the plaintiff in the accounting to present prima facie evidence of the number of devices and their monetary value, the evidence upon which plaintiff is forced to rely for this purpose is usually in the form of records and documents in the possession of [fol. 145] defendant, and this is especially true where the devices have been acquired by the infringer from third parties, as in the present case.

Where confusion in the books or records of the defendant is found, or where profits from the infringing device have been commingled with other profits of the defendant, it is obviously impossible for the plaintiff to proceed beyond a

certain point in its prima facie proof, and one party or the other must suffer. We find no better exposition of this subject than that given in *Westinghouse Co.* v. *Wagner Mfg. Co.*, 225 U. S. 604, 621, from which we quote at some length:

None of the cases cited discuss the rights of the patentee who has exhausted all available means of apportionment, who has resorted to the books and employes of the defendant, and by them, or expert testimony proved, that it was impossible to make a separation of the profits. This distinction, between difficulty and impossibility, is involved in the ruling by the Circuit Court of Appeals for the Sixth Circuit in *Brennan & Co.* v. *Dowagiac Mfg. Co.*, 162 Fed. Rep. 472, 476, where the *Garretson Case* was distinguished, and the court said:

"In the present case the infringer's conduct has been such as to preclude the belief that it has derived no advantage from the use of plaintiff's invention. * * * In these circumstances, upon whom is the burden of loss to fall? We think the law answers this question by declaring that it shall rest upon the wrongdoer, who has so confused his own with that of another that neither can be distinguished. It is a bitter response for the court to say to the innocent party, 'You have failed to make the necessary proof to enable us to decide how much of these profits are your own;' for the party knows, and the court must see, that such a requirement is impossible to be complied with. The proper remedy to be applied in such cases is that stated by Chancellor Kent in *Hart* v. *Ten Eyck*, 2 Johns. Ch. (N. Y.) 62, 108, where he said: 'The rule of law and equity is strict and severe on such occasion. * * * All the inconvenience of the confusion is thrown upon the party who produces it, and it is for him to distinguish his own property or lose it.' "

It may be argued that, in its last analysis, this is but another way of saying that the burden of proof is on the defendant. And no doubt such, in the end, will be the practical result in many cases. But such burden is not im- [fol. 146] posed by law; nor is it shifted until after the plaintiff has proved the existence of profits attributable to his invention and demonstrated that they are impossible of accurate or approximate apportionment. If then the burden of separation is cast on the defendant it is one which justly should be borne by him, as he wrought the confusion.

See also *Computing Scale Co.* v. *Toledo Computing Scale Co.*, 279 Fed. 648, 673, which refers to the *Westinghouse* decision as follows:

> And the first fruits of the Westinghouse decision should be this: If a manufacturer, knowing of a patent, decides to chance an unlicensed use, he should realize that he may be caught by a final decree on the merits and be ordered to respond accordingly; and, so realizing, he should be held to the duty of keeping separate and accurate records of all his infringing acts; and, on his failure to keep such records, the court, in measuring the damages on account of his trespasses, should resolve all doubts against him.

In the present case there was a commendable cooperation between counsel with respect to the examination of defendant's records. In lieu of calls, the complete files in the General Accounting Office with respect to specified contracts for the purchase of radio apparatus were rendered available to a representative of plaintiff who made abstracts of them, these abstracts being submitted to a representative of defendant for correction and the addition of any material it desired. Any informal requests for the production of documents from the defendant's records that could be located were granted and plaintiff's representative permitted to examine them and make abstracts. It is from these abstracts with very few exceptions, that the plaintiff has based its proof of the number of sets and their market value.

With respect to the majority of the items questioned by plaintiff, plaintiff urges that the contract files show a contract for delivery of a certain number of radio sets at the given market value, and contain no record either of cancellation, payment for, or acquirement of the sets by the defendant, and under these circumstances plaintiff asserts that the delivery of and payment for the apparatus in accordance with the terms of the contract, and in the absence [fol. 147] of any proof to the contrary on the part of defendant, must be inferred or presumed.

In so far as three of the contested items are concerned they should be included. Item A-27 (see Finding 11) called for a transmitting and receiving set at a price of $2,450. The abstract of this contract shows no record of payment in the contract file. In plaintiff's Exhibit 428 however (Item 9) there is an official notice dated March 17, 1913, referring to this contract and stating, "The balance of the material

on order 12387 was to-day inspected and accepted." We think in this instance that the burden of proof as to the non-acquisition of this set is on defendant, and this item has been included in the accounting.

With respect to the Tuckerton transmitting set (Finding 11) there is no contract file in evidence, but plaintiff's witness Clark has testified that a 60-kw. arc transmitting set was supplied by the Federal Telegraph Company and he personally installed this set at the Tuckerton station. Mr. Clark, who also had a great deal to do with the preparation of the various Navy contracts and was well acquainted with the value of the apparatus, also gave as his opinion that the value of this set was $8,000. We think that this oral testimony of Mr. Clark is sufficient to establish acquirement of this set and its value in the absence of any proof by defendant to the contrary.

Defendant's witness Eaton described three radio receivers which he had constructed and used on behalf of and as an employee of defendant during the Lodge accounting period. The source of or date of acquirement of the various component elements used in the construction of these receivers is unknown, but even grating that the component parts of these sets were acquired prior to the Lodge accounting period, these sets did not become an entity until they were constructed or manufactured. This act took place during the Lodge accounting period. The minimum established value of a receiving set during the Lodge accounting period was $250, and these three receivers, at a total of $750, are therefore included in the accounting (see Finding 11). The defendant has presented no proof to the contrary with respect to this item.

[fol. 148] It it to be noted in connection with the first of these three items (Item A-27) that while the contract file itself indicated no proof of payment, there was separate proof of acceptance or acquisition of the radio apparatus by the defendant. We emphasize this in passing to a consideration of some of the other items which plaintiff urges for inclusion in the accounting. While admissible in evidence to lay a foundation, we do not think that the mere existence of a contract under the circumstances in the present case carries the presumption of acquirement of the apparatus specified.

In the present situation and from a consideration of the plaintiff's abstracts and documents in their entirety, it can

not be said that the Government has kept a confused or inaccurate record. Instead, we are convinced from an examination that these records as a whole are more complete and accurate than similar records kept by the average private firm or individual and relating to events occurring as far back as 1913-1915. Neither can it be said that the defendant did not extend cooperation to plaintiff in its examination of its records. We also do not think that plaintiff has satisfactorily established as a fact that where a contract file in the General Accounting Office does not show either a cancellation of the contract or a fulfillment of the contract, the records have been inaccurately kept. It would appear that this statement, upon which plaintiff predicates the shifting of the burden of proof, is more of an assumption than an established fact.

With reference to the shifting of the burden of proof to the defendant, we refer to the *Westinghouse case* cited, *supra*, directing attention to the fact that such burden is not shifted until the plaintiff has proved the *impossibility* of either accurate or approximate apportionment, this case referring to the distinction between *difficulty of proof* and *impossibility of proof* in the first paragraph of the subject-matter cited therefrom, *supra*.

We now refer to Item A-5 (Finding 12), which is one of the items plaintiff urges should be included in the accounting. This item is an abstract of a contract with the Federal Telegraph Company dated November 2, 1914, and [fol. 149] called for one transmitter and one receiver at a contract price of $5,500. The abstract of this contract states that there is no payment by public bill or any other record of payment, nor does the abstract of the contract specify the delivery date of the apparatus. From what we have previously said, we cannot assume from this abstract that defendant acquired this apparatus or that further evidence by plaintiff with respect to this item is an impossibility rather than a difficulty.

What we have said about this item applies also to the various other items set forth in detail in Finding 12 and with reference to which it is therein stated that there is no satisfactory evidence either of delivery of or payment for the items within the accounting period.

What we have said with respect to Item A-5 as to proof applies also to such items as 50 and A-35 in Finding 10. Item 50 calls for five radio sets and shows delivery of two

of them during the Lodge accounting period. There is no proof of delivery of or payment for the remaining three sets during the accounting period. Item A-35 similarly shows a contract for thirty radio receivers and delivery of and payment during the Lodge accounting period for twenty-three of the receivers, with no proof of delivery of or payment for the remaining seven.

It is unnecessary to refer in detail to the remaining items which plaintiff urges should be included or altered as to market value in the accounting (Items A-1, A-29, A-39, B-20, B-21, B-52, and C-1) and which we have set forth in detail in Findings 9, 10, and 12. The commissioner was correct in either excluding the items or in giving them the market values proved by the records of payment in the files.

From the tabulation appearing on pages 6 and 7 the entire market value of the apparatus acquired during the Lodge accounting period is $348,276.94.

We find that just and reasonable compensation is 10 percent of this entire market value, or $34,827.70, together with an amount measured by interest at 5 percent per annum, not as interest but as a part of the entire just compensation, on $34,827.70 from August 16, 1915, to date of payment of the judgment.

[fol. 150] Defendant in its exceptions to the commissioner's report has requested that the court use an interest figure of 2 percent because, and to quote from its exceptions:

> Just compensation should not include interest at a higher rate and should not include interest prior to April 8, 1936, because the plaintiff by joining the claim under the Lodge patent with claims under three other patents contributed to protraction of the litigation beyond all reason, when the claim under the Lodge patent could easily have been separated and promptly tried.

We do not follow this line of reasoning. It is apparently based on a false premise, for if the Lodge patent were to be separated, then presumably each of the other patents should likewise have been separated, with the result that there would have been four distinct suits in which a substantial part of the record would have had to be duplicated. The joinder of the four patents in one suit, all owned by plaintiff and directed to the same basic subject-matter, simplified the litigation by making it possible to consider

only once all fundamental matters relating to radio, relationships between the parties, and the facts as to the acquirement and structure of the infringing apparatus.

Defendant does not suggest that there has been any unreasonable delay in the prosecution of this case, with its necessarily voluminous record. In fact, in its objections to plaintiff's proposed findings of fact before the commissioner, filed September 9, 1940, defendant stated (p. 20):

> The highly technical character of the subject-matter, the difficulty of assembling competent witnesses, and the time required for preparation by both parties are believed to be such as to indicate reasonable speed by both parties.

We feel from a consideration of the record that 5 percent is a proper rate of interest in the present case.

Marconi Patent 763,772

Plaintiff having filed supplemental petitions, the accounting period for the Marconi patent extended from July 29, 1910, to November 20, 1919, at which time the plaintiff [fol. 151] assigned the patent. Claim 16 upon which this accounting is based relates to a particular circuit connection between the antenna tuning condenser and the primary of the transformer in a radio receiver, hereinafter referred to as the parallel or shunt connection. Findings 20 and 21 recite the claim and describe the circuit in detail.

In connection with this patent the defendant presents an issue unusual in accounting proceedings, i. e., the issue of noninfringement. The two other basic issues presented by the parties are whether certain radio receivers should be included in or excluded from the accounting, and what proportion of the monetary value resulting from the use of the invention by the defendant should be utilized in arriving at a reasonable and entire compensation.

In its opinion of November 4, 1935, on the question of validity and infringement of the Marconi patent, which was at that time before the court, the third conclusion of law of this court read as follows:

> That the Marconi patent #763,772 is invalid except as to claim 16 thereof, which is infringed by the apparatus specified in Finding LXIII and any other apparatus used by defendant coming within its terminology.

We also quote Finding LXIII, referred to in this conclusion of law:

> The receiving apparatus of the Kilbourne & Clark Company, shown in exhibit 95, and the receiver made by the Telefunken Company, illustrated in exhibit 79, each has apparatus coming within the terminology of claim 16.

In connection with the presentation to the court of the question of validity and infringement, it had been stipulated that the issue of reasonable compensation for damages and profits be postponed until the determination by the court of the issues of validity and infringement of the various patents in suit.

The decision of this court relative to infringement and validity (November 4, 1935) was prior to the *Esnault-Pelterie* decision of December 7, 1936 (299 U. S. 201), which held that infringement was a question of fact rather than one of law. Prior to the *Esnault-Pelterie* decision this court [fol. 152] uniformly considered that whether or not certain apparatus came within the terms of a patent claim was a question of fact, but that whether the claim was infringed by such apparatus was a question of law.

The defendant some six years after the original decision of this court on the question of infringement, and after the expenditure of much time and money in the Marconi accounting, now for the first time argues that there was *no finding of fact* that the defendant has infringed and asks for a finding of noninfringement. Thus as we see it, defendant's present position, based upon this technicality, is that this court in spite of the stipulation that the accounting be deferred until validity and infringement had been determined, sent this case to the commissioner for the accounting without deciding the issue of infringement of claim 16. This we did not do. The meaning and intent of the prior decision on infringement was clear and was understood by the defendant who at no time by motion for a new trial or otherwise has until now questioned the correctness or the sufficiency of the court's findings or conclusions.

In its eagerness to advance this theory of noninfringement defendant has evidently overlooked the fact that should the court still consider this question as pending in Marconi patent #763,772, plaintiff could with equal facility urge that the prior conclusion of the court holding the

Marconi reissue patent and the Fleming patent noninfringed, was equally nondeterminative.

The question of infringement of Marconi claim 16 by the apparatus designated in Finding LXIII of the prior decision is not before us in the present accounting. In order to forestall further controversy, however, we have found validity and infringement as an ultimate fact (Findings 1 and 23) in our special findings of fact.

In its argument as to noninfringement defendant also attempts to rely upon a ruling of this court on defendant's motion with respect to certain calls under date of October 22, 1937. The court's order read:

> The location and function of the condenser in the Government radio sets under consideration in the present motion is a question of fact, and their identity or difference of construction and mode of operation with respect to claims [fol. 153] which have been held valid and infringed are subject to proof before the Commissioner. The within motion is overruled.

Defendant suggests that by this order the court reopened the entire subject of infringement of claim 16. This is incorrect. This order resulted from the fact that plaintiff had made motions for calls on certain Departments relating to additional apparatus which plaintiff claimed infringed claim 16 of the Marconi patent. Plaintiff's motions were allowed but defendant requested this court to reconsider its allowance of the motions, and in support of its argument numerous radio circuit diagrams were submitted to the court without any expert testimony as to what they disclosed. The court denied defendant's motion to reconsider the allowance of plaintiff's motions for calls, and left it to the commissioner to determine by means of evidence presented before him the location and function of condensers in defendant's receivers. The order in substance required the commissioner to determine whether these additional receivers should be included in or excluded from the accounting.

The defendant also argues that even though claim 16 be valid, it is limited in scope by the prior art, and as thus limited the Government receivers follow the teachings of the prior art rather than claim 16 of the Marconi patent, and therefore do not come within the accounting. Defend-

ant asserts that the commissioner failed to make certain findings bearing out this contention. This of course is but raising the question of infringement in another guise.

The court in its original decision established the scope of claim 16 when it held the same infringed by the receivers of the Kilbourne & Clark Company and the Telefunken Company, as set forth in Finding LXIII. This apparatus, its circuits and its elements establish the interpretation of the claim with respect to the accounting.

The sole purpose and function of an accounting in a patent infringement case is to ascertain the amount of compensation due, and no other issue can be brought into the accounting to change or alter the court's prior decision. With reference to the additional receivers presented, if [fol. 154] their identity of construction and mode of operation are similar to the apparatus which the court has held to be an infringement, then they also infringe, and this is as far as the proof has to go. See *Flat Slab Patents Co. v. Turner*, 285 Fed. 257, 273:

> The problem of the master, therefore, in ascertaining whether a new construction is to be covered by the accounting, becomes *one of comparison between that construction and the one declared to infringe*. This comparison is along the line of infringing elements or features. The identity of such elements or features and the respect in which they constitute infringements can be found by the master sometimes in his report or more often in his opinion which may be treated as an explanation of the report. No aid in understanding the action of the court can be found in facts not before the court as evidence and not judicially noticeable. Evidence of the prior art can find no initial entrance into the case through the accounting. The place of prior art in patent law is to invalidate or limit the scope of the patent. The suggestion that it can be introduced for the first time in the accounting for the purpose either of modifying or of interpreting the infringement adjudication is not sound. The duty of the master is to apply, not to alter the decision of the court appointing him, and he is not aided in understanding that decision by facts which the court did not have in mind when it acted. [Italics ours.]

It is clear from the record that the construction and mode of operation of the additional receivers were similar to

the Kilbourne & Clark receiver and the Telefunken receiver when the antenna tuning condenser was connected in the parallel position. None of defendant's witnesses has asserted to the contrary, and we have so found in Finding 24.

The technical details of construction of the various groups of receivers contained in the itemized schedule forming a part of Finding 32 are set forth in Findings 35 to 39, inclusive. The usual controversy has arisen as to the inclusion or exclusion of certain individual items of equipment. We have fully discussed the matter of proof in this respect in that portion of the opinion relating to the Lodge patent, and it is unnecessary to repeat it here. These items have been considered in accordance with our previous statement and are set forth in Findings 33 and 34.

[fol. 155] With respect to the various groups contained in the itemized schedule (Finding 32), the first group, "Receivers with permanently connected parallel condenser," needs no explanation. As constructed, these receivers have what we term for convenience "the Marconi circuit" in permanent form.

As to Group I, the receivers therein had an automatic device connected with the inductance controlling knob of the set so that when the knob was in its last positions the circuits inside the set were so arranged as to produce the Marconi circuit.

Receivers within Group II were provided with a switch so that the operator could connect at will the condenser either in series or utilize the Marconi circuit.

The item in this group identified as "Montcalm" refers to a group of receivers which were made and used at the United States Naval Radio Station at the American Legation in Peking and within the legation grounds. This item, which is trivial, as it involves only 10 receivers out of a total of 4,007, presents an apparently new issue in patent law. Does manufacture and use in such a location violate the monopoly created by the patent and which extends "throughout the United States, and the Territories thereof," as expressed by Section 4884 of the Revised Statutes?

We know of no case directly in point. *Gardiner* v. *Howe*, 9 Fed. Cases 1157, however, is a patent case in which the master of a vessel under American registry applied a device to a sail and used the same while on the high seas between

Liverpool and New York. The owner of the vessel was made the defendant in a patent suit for this act. The court held that use of the invention of a United States patent on a vessel of American registry, while it is on the high seas and without the jurisdiction of the United States, constitutes infringement of the patent. Justice Clifford said:

The patent laws of the United States afford no protection to inventions beyond or outside of the jurisdiction of the United States; but this jurisdiction extends to the decks of American vessels on the high seas, as much as it does to all the territory of the country, and for many purposes is even more exclusive.

[fol. 156] The converse of this proposition is set forth in *Brown v. Duchesne*, 19 How. 183, where Mr. Justice Taney held that the exclusive rights granted to a patentee do not extend to a foreign vessel lawfully entering one of our ports and that the use of the patented improvement in the construction, fitting out, or equipment of such vessel, while she is coming into or going out of a port of the United States, is not an infringement of the rights of an American patentee provided such use is lawful under the laws of the country to which the vessel belongs.

We think from these two cases the use of a United States patent on the grounds of the American Legation at Peking constitutes infringement thereof, and the ten receiving sets are properly within the accounting.

Receivers in Group IIIA were what might be termed universal receivers. These sets were intentionally designed under the supervision of Navy engineers to employ three different circuit connections at the will of the operator, who could use either a series condenser connection, a connection involving an external load coil, or the Marconi circuit. In order to accomplish this, the sets were designed with the condenser connected between the ground and the primary coil instead of its more conventional location between the antenna and the primary coil, and instead of having all the wiring of the sets permanent in character and behind the panel, the necessary wires were brought out to binding posts mounted on the face of the panel. The binding posts were identified by engraved legends, and by means of making various connections to them the operator could select any of the three modifications which he desired. An instruction book with diagrams for the operators ac-

companied these sets and this book told the operator what connections to make in order to obtain the Marconi circuit and also referred to its utility.

The receivers in Group IIIB were identical with those in IIIA as to construction and the location of the binding posts on the panel for obtaining any of the several types of receiving circuits, including the Marconi circuit. The receivers in this group, however, were not accompanied by an in- [fol. 157] struction book with specific references to the Marconi circuit.

The evidence in the case is clear that the Navy wireless operators had knowledge of the advantages of the Marconi circuit and utilized this circuit from time to time in the reception of official Navy communications and in accordance with the orders of their superior officers in the use of Group IIIB receivers as well as Group IIIA receivers. Both of these groups are therefore properly included in the accounting. See *Wright Co.* v. *Herring-Curtiss Co.*, 211 Fed. 654, 655, as follows:

> As to the other claims, in which the vertical rear rudder is an element, we are satisfied from the testimony, as was the court below, that during some parts of their flight defendant's machines use the rudder synchronously with the wings, so that by their joint action lost balance may be restored or a threatened loss of balance be averted. Such use of the rudder constitutes infringement, and a machine that infringes part of the time is an infringement, although it may at other times be so operated as not to infringe.

See also *Corrugated Fiber Co.* v. *Paper Working Machines Co.*, 259 Fed. 283.

The Marconi invention as predicated upon claim 16 relates only to a portion of the receiving set, i. e., the primary tuning condenser and its circuits. As the contract costs of sets acquired by the Government in most instances relate to the complete receiver and include detector devices and improvements which should be properly allocated to other patentees, there would be great difficulty in segregating the value of those portions of the receivers involved in this accounting. Use has therefore been made of the standard of comparison method.

If the defendant had not used the Marconi circuit it would have been possible to accomplish substantially the

same basic results by the use of another type of tuning circuit available to the defendant but at an increased cost. Compensation may therefore be arrived at by ascertaining these costs. As the detailed method and computations are set forth fully in Findings 26-30 and 40-44, inclusive, it is unnecessary to refer to this method here except to state [fol. 158] that it involved calculations of the cost of the alternate structure available to the defendant and included materials, labor, and overhead.

The final tabulation in Finding 45 gives the total cost estimate of this alternate structure, being indicated both by suitable periods of time and by groups.

The total figure is $66,130.67 for the 4,007 receivers coming within the accounting.

Plaintiff contends that it is entitled to this total value, together with suitable interest thereon, as reasonable and entire compensation. With this we do not agree. This value does not represent profits lost by the plaintiff through the failure of the defendant to purchase from it receiving sets equipped with the Marconi circuit. Nor is this figure the measure of the infringer's profits such as occurs frequently in patent litigation, where the defendant has obtained a market by the unauthorized use of an invention and which profits then become a measure of damages.

Instead, this figure represents the entire sum that it would have cost the defendant to avoid the use of the Marconi invention by accomplishing the same results in another way. If the parties to this suit had been in negotiation for the use of the Marconi invention we can readily assume that the price agreed upon would be something less than it would have cost defendant to use an equivalent device, for, unless this were done, the defendant as a party to this negotiation would receive absolutely no benefits. See *Olsson* v. *The United States*, 87 C. Cls. 642, 659, quoting from *Mamie C. Wood et al.* v. *United States*, 36 C. Cls. 418, 426:

> But this court, in the leading *Case of McKeever* (14 C. Cls. R., 396; affirmed by the Supreme Court, see 18 id., 757), laid down a sufficient rule for such cases. The question to be determined is, What was the invention worth in the market? What would the parties have taken and paid if the matter had come to an express agreement? What would any person needing the invention have been willing to pay for it? * * *

Upon the record in this case, we are of the opinion that 65 per cent of $66,130.67, the total monetary value of the utility and advantages to the Government, or the sum of $42,984.93, constitutes a reasonable and entire compensation [fol. 159] to plaintiff for the use by the United States of the Marconi invention, together with interest at 5 per cent on this amount, not as interest but as a part of the just compensation, this interest to be calculated in accordance with the periods and amounts specified in the tabulation in Finding 47.

In this accounting, which relates to Lodge patent No. 609,154 and Marconi patent No. 763,772, plaintiff is entitled to judgment in the sum of $34,827.70, with interest at 5 per cent per annum thereon, not as interest but as a part of just compensation, from August 16, 1915, until paid, as to the Lodge patent; and as to the Marconi patent the sum of $42,984.93, with interest on the several amounts and from the dates specified in Finding 47 until paid, not as interest but as part of just compensation.

It is so ordered.

Green, Judge; Madden, Judge; Jones, Judge; and Littleton, Judge, concur.

[fol. 160] VIII. Judgment of the Court

At a Court of Claims held in the City of Washington on the 6th day April, A. D., 1942, judgment was ordered to be entered as follows:

Upon the foregoing special findings of fact, which are made a part of the judgment herein, the court decides as a conclusion of law that plaintiff is entitled to recover the sum of $77,812.63 with interest at 5 per cent per annum, not as interest but as part of just compensation.

It Is Therefore Adjudged and Ordered that the plaintiff recover of and from the United States the sum of seventy-seven thousand, eight hundred twelve dollars and sixty-three cents ($77,812.63), with an additional amount measured by interest at the rate of 5 per cent per annum on the following sums from the dates specified until paid: $34,827.70 from August 16, 1915; $109.78 from December 31,

1911; $754.97 from December 31, 1913; $422.66 from December 31, 1915; $15,789.72 from December 31, 1918, and $25,-907.80 from November 20, 1919.

[fol. 161] IX. PROCEEDINGS AFTER JUDGMENT

On June 23, 1942, the plaintiff filed a request for record under Rule 99(a), together with Petition for Writ of Certiorari and other parts of the evidence agreed to by parties as material to errors assigned.

[fol. 162] X. PARTS OF EVIDENCE AGREED TO BY PARTIES AS MATERIAL TO ERRORS ASSIGNED

See Volumes Nos. 1 to 7 incl., paged from 1 to 3289 transmitted herewith.

[fol. 163] XI. ORDER OF COURT SETTLING RECORD

The plaintiff having filed a petition for writ of certiorari to the Supreme Court in the above-entitled case, and both plaintiff and defendant having requested that certain portions of the evidence which were agreed to by them, and which are attached hereto be included in the record to be certified to the Supreme Court, and the court having found that said portions are accurate transcripts of the original record material to the errors assigned, the same are hereby this 27th day of June, 1942, approved as the record to be certified to the Supreme Court.

By the Court;

Richard S. Whaley, Chief Justice.

[fol. 164] Clerk's Certificate to transcript omitted in printing.

[fol. 165] IN UNITED STATES COURT OF CLAIMS

No. 33,642

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA, Plaintiff,

vs.

THE UNITED STATES, Defendant

Parts of Evidence Agreed to by Parties as Material to Errors Assigned

[fols. 166-167] EVIDENCE FOR PLAINTIFF

[fol. 168] *Deposition of John Bottomley, for claimant, taken at New York, N. Y., on the 17th day of April, A. D. 1917, and subsequent dates*

Claimant's counsel, James J. Cosgrove; defendant's counsel, Henry C. Workman.

JOHN BOTTOMLEY deposes and says that his name is John Bottomley; that he is 69 years of age; that his residence is New York City; and occupation is that of vice president, secretary, and treasurer of the Marconi Wireless Telegraph Co. of America. "I am in no wise personally interested in the claim in controversy."

John Bottomley, being interrogated by Mr. Cosgrove, testified as follows:

1. Question. For how long have you been connected with the claimant company and in what capacities?

Answer. Prior to 1902 and from 1898 I acted as assistant counsel for the company. In the year 1902 I became general manager, and from that time forward I have been variously connected with the company as general manager, vice president, secretary, and treasurer.

• • • • • • •

[fol. 169] 7. Question. If you can, please identify and state what the papers are which are now handed you, and what knowledge any of the officers of the United States Government have had in relation to the litigation over the patents in suit, so far as you know.

Answer. The first letter I identify as a press copy of a letter written by me, dated February 28, 1911, addressed to

the Bureau of Steam Engineering, Washington, D. C., informing the bureau of a complete decision rendered in the high court of England in favor of Marconi's Telegraph Co. (Ltd.), in an action brought against the British Radio Telegraph & Telephone Co., for infringement of wireless apparatus, covered by British patent No. 7777, completely covering the art of tuning, inclosing a clipping showing the decision more fully and drawing the attention of the bureau to the fact that the Marconi Wireless Telegraph Co. of America holds patents issued by the United States Government No. 763772, dated June 28, 1904, on identically the same lines as those above referred to, and bringing to the notice of the bureau the intention of my company to at once commence action to sustain the validity of this patent. I also identify a letter, dated March 3, 1911, from the Navy Department, Bureau of Steam Engineering, signed by R. S. Griffin, acting chief of the bureau, acknowledging receipt of the letter above referred to and of the notice that we were about to commence action. I also identify a letter, dated March 7, 1911, addressed to the Bureau of Steam Engineering, Navy Department, Washington, D. C., signed by myself inclosing copy of the decision. I further identify a letter, dated March 11, 1911, from the Navy Department, acknowledging receipt of the "Electrician." I further identify a letter, dated March 7, 1911, addressed to George von L. Meyer, Secretary of the Navy, signed by me as vice president, fully referring to the above judgment, and inclosing a clipping from the New York Times.

I further identify a letter dated March 18, 1911, addressed to George Von L. Meyer, Secretary of the Navy, signed by me at vice-president and inclosing a pamphlet describing the action above referred to and giving excerpts from the judge's decision. I further identify a letter dated March 22, 1911, from the Navy Department, Bureau of Steam Engineering, signed by the acting chief of bureau, acknowledging the pamphlet. I further identify a letter dated May 19, 1911, addressed to the Secretary of the Navy and signed by me as vice president, and inclosing a notice sent out to all makers and users of wireless telegraph apparatus in the United States, to establish action, setting up the validity of our American patent No. 763772, otherwise known as the "four-circuit" or tuning patent. I further identify a letter dated May 19, 1911, signed by me and addressed to the Navy Department, Bureau of Steam Engi-

neering, on the same lines as the letter last above identified. I also identify a letter dated May 23, 1911 from the Navy Department, Bureau of Steam Engineering signed by H. J. Cone, engineer in chief, acknowledging the receipt of the letter last mentioned. I also identify a letter dated March [fol. 170] 6, 1911, addressed to the chief officer of the Signal Corps, U. S. A., Washington, D. C. signed by me as vice president and drawing attention to the judgment in the action first above referred to. Also a letter dated March 18, 1911, addressed to the same signed by me and inclosing clipping and pamphlet relating to the action last mentioned. I also identify a letter dated March 23, 1911, from the War Department signed F. Allen, brigadier general, acknowledging receipt of the pamphlet. I also identify a letter dated May 19, 1911, addressed to the U. S. Army Corps, inclosing a notice in relation to American patent 763772. I also identify a letter dated October 28, 1911, signed by me as general manager, addressed to Major Squier, U. S. Signal Corps, inclosing a copy of Judge Parker's decision in the action last above mentioned. I further identify a letter dated November 3, 1911, from the War Department, signed by J. Allen, brigadier general, acknowledging receipt of the last letter.

* * * * * * *

10. Question. Please look at the document now handed you and say if you know what it is and what bearing it has on the British decision or judgment referred to in your letters forming part of plaintiff's Exhibit No. 6.

Answer. This paper which I hold in my hand is a copy of the decision or judgment rendered in the high court of justice by Mr. Justice Parker in the case of Marconi and others *v.* The British Radio Telegraph & Telephone Co. (Ltd.) and referred to in the letters just above identified, being an action for infringement of Marconi British Letters Patent 7777 of the year 1900 for improvements in apparatus for wireless telegraphy.

Mr. Cosgrove. Claimant's counsel now offers in evidence the copy of the decision or judgment just identified by the witness and asks that the same be marked "Plaintiff's Exhibit No. 7, Mr. Justice Parker's decision."

* * * * * * *

[fols. 171-172] 11. Question. You have referred to the Marconi patent in suit, No. 763772, as the tuning or "four-circuit patent." I direct your attention to page 133 of the printed record of the hearings in the year 1917 before the Committee on the Merchant Marine and Fisheries of the House of Representatives of the Sixty-fourth Congress on bill No. 19350, to regulate radio communication, which page purports to contain a statement of testimony of David W. Todd, of the United States Navy. Do you find any reference to that four-circuit patent in that testimony; and if so, will you please read it on the record?

Answer. I find in the evidence given by Commander Todd, above referred to, the following, on page 133:

"* * * With special reference to one of the basic patents of radiotelegraphy known as 'the four-circuit patent.' This is used practically in all radio apparatus, both transmitters and receivers, and the claims of various people so overlap and have resulted in so much controversy that the Navy Department was not able to decide whether or not those claims were extravagant or real or otherwise, and the courts have not been able to do so, either. It is still in the courts, and it is on that same patent that the Government is being sued. * * *"

* * * * * * *

[fol. 173] 23. Question. Please look at the papers now handed to you and identify them if you can and state what they relate to.

Answer. Papers in my hands are press copies of letters signed by me and originals from the Navy Department, Bureau of Steam Engineering, sent during the month of October, 1910, informing the bureau that Com. G. Marconi had received perfect signals in the Argentine Republic from Clifden, Ireland, and Glace Bay, N. S., and offering to make test of reception in the Navy of distances up to 3,000 miles, without expense to the U. S. Government; a letter signed by me and sent to the Bureau of Steam Engineering authorizing installation of this receiving apparatus on the battleships *Louisiana* and *New Hampshire*, and showing that the tests were not accepted by the Navy Department but that the Marconi company offered to give the battleship the use of

our very sensitive valve receiver and asking for shipping instructions of the receiver.

*   *   *   *   *   *   *

[fol. 174] 25. Question. What do you know as to whether or not the valve receiver, referred to in your letter of October 25, 1910, mentioned in answer to question 23 was ever sent to the Navy Department for use or test?

Answer. The Fleming valve receiver was sent to the Navy Department on October 24, 1910, for use on the *Louisiana* or *New Hampshire*, or in such other way as the Navy Department might elect.

26. Question. Do you know whether or not this Fleming valve receiver was ever installed on the battleship *Louisiana?*

*   *   *   *   *   *   *

Answer. Not to my personal knowledge.

*   *   *   *   *   *   *

28. Question. Please look at the article now shown you and state if you know what it is and read on the record any marking it has thereon.

Answer. This is the Fleming valve receiver which was sent to the Navy Department at Norfolk Navy Yard and is marked "Marconi Wireless Telegraph Company of America, No. 5015, New York, U. S. A. patent No. 803684."

Mr. Cosgrove. Claimant's counsel requests that the receiver identified by the witness in the last answer be marked for identification "Fleming valve receiver."

29. Question. Please look at the book I hand you and state what it contains.

Answer. This is a Marconi shipping-order book and contains shipping orders, and one, No. B638, October, 1910, showing the shipment to Neil McIntyre, S. S. *Louisiana*, Norfolk Navy Yard, Norfolk, Va., of, with other apparatus, one valve CC receiver, No. 5015, which is the valve receiver last above mentioned.

[fols. 175-176] Mr. Cosgrove. Plaintiff's counsel requests that the shipping order No. B638, referred to by the witness, be marked for identification.

*   *   *   *   *   *   *

32. Question. To what extent has the plaintiff company supplied the United States Government with wireless telegraph apparatus manufactured by the company?

Answer. Our books show that we have sold to the United States Government and its various departments manufactured apparatus to the extent of about $350,000.

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[fol. 177] Cross-examination.

By Mr. Workman:

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42. Cross-question. Referring to the letter introduced in your evidence, plaintiff's Exhibit No. 13, dated October 6, 1910, you have no definite knowledge, have you, of the reception of signals referred to in that letter, from Clifden, Ireland, and Glace Bay, N. S., was by means of the Fleming so-called valve patent?

Answer. No; I have not any knowledge of that, not having been personally present, but we were so informed by Mr. Marconi, who conducted the test.

43. Cross-question. Could you describe a valve receiver so that the court would understand its construction and operation?

Answer. I could not.

44. Cross-question. Do you have any personal knowledge of your own that the valve receiver referred to in the letter of October 25, 1910, forming part of plaintiff's Exhibit No. 13, was the valve receiver patented in the Fleming patent in suit?

Answer. I have no actual personal knowledge on the subject; my information was derived from our chief engineer, who is our technical adviser.

45. Cross-question. Do you have any personal knowledge of your own that the exhibit marked for identification "Fleming valve receiver" was sent to the Navy Department at any time?

Answer. I have not any personal knowledge that it was so sent, but I was informed by our chief engineer that it had been sent, and I saw it in our store after it had been returned and was informed that it had been returned. I mean this identical piece of apparatus.

46. Cross-question. Have you any knowledge of your own whether or not, assuming that the exhibit referred to was sent to the Navy Department as you have testified, that when it was sent it was in the same condition as it is now?

Answer. I have not any personal knowledge.

[fols. 178-179] 47. Cross-question. I note there are two sockets on the black platform of this receiver. Do you know what they are for?

Answer. I believe these sockets were holding glass bulbs in connection with the receiver.

47. Cross-question. There is nothing in either of these sockets on this exhibit now, nor when it was introduced in evidence yesterday. That is correct, is it?

Answer. That is correct.

48. Cross-question. You have no knowledge as to whether or not the sockets had something in them when it was sent to the Navy Department, as you have testified, have you?

Answer. I have no personal knowledge.

49. Cross-question. Are you aware that there are a number of receivers used in wireless apparatus that have been called valve receivers?

• • • • • • •

Answer. I am not a technical man and I do not know what valves are supposed to be made and used and called receiving valves.

• • • • • • •

[fol. 180] "By Mr. Cosgrove. Plaintiff's Counsel offers in evidence the following:

"A certified copy, including the grant of the re-issue letters patent in suit, #11,913, dated June 4, 1901 to Marconi Wireless Telegraph Company Limited and requests the same to be marked Plaintiff's Exhibit #19, Marconi Re-Issue patent.

"Certified copy, including the grant of the letters patent in suit to Lodge #609,154, dated August 16, 1898, and requests that the same be marked Plaintiff's Exhibit #20, Lodge patent in suit.

"Certified copy, including the grant of the Marconi Letters Patent in suit, No. 763,772, dated June 28, 1904, issued

to Marconi Wireless Telegraph Company, Limited, applied for Nov. 10, 1900, Serial No. 36,010, and asks that the same be marked Plaintiff's Exhibit #21, Marconi patent in suit, #763,772.

"Certified copy including the grant of the Fleming patent in suit #803,684, dated Nov. 7, 1905, application filed April 19, 1905, Serial No. 256,483, issued to the Plaintiff Company, and requests that the same be marked Plaintiff's Exhibit #22, Fleming patent in suit #803,684.

• • • • • • •

[fol. 181] "Printed copy of Marconi British Patent #7777 of 1900, and requests that the same be marked Plaintiff's Exhibit #34, Marconi British Patent.

"Copy of the decision or judgment of Mr. Justice Eves in the English High Court of Justice in the suit of G. Marconi Wireless Telegraph Company *vs.* The Helsby Wireless Telegraph Company.

[fol. 182] *Deposition of John Brennen, for claimant, taken at New York, N. Y., on the 18th day of April, A. D. 1917*

Claimant's counsel, James J. Cosgrove; defendant's counsel, Henry C. Workman.

John Brennen deposes as follows:

1. Question. State your name, your occupation, your age, and your place of residence , whether you have any, and if any, what interest, direct or indirect, in the claim which is the subject of inquiry, and whether and in what degree you are related to the plaintiff.

Answer. John Brennen, assistant to Mr. Sawyer, general superintendent of the maintenance, repair, and inspection division of the Marconi Wireless Telegraph Co. (New York division); 45 years of age; residing in Jersey City; no interest in the claim in controversy.

2. Question. How long have you been connected with the Marconi Wireless Telegraph Co. of America, the plaintiff herein?

Answer. Since June, 1904.

3. Question. In what capacities have you been connected with the Marconi company since June, 1904?

Answer. I was sort of acting as superintendent in repairing and installing apparatus, and also manufacturing when necessary.

4. Question. In what shops of the Marconi company have you been working?

Answer. 37 Water Street, New York City; 125 Front Street, 29 Cliff Street, and 25 Elm Street—that is our present place—in New York City.

5. Question. At what work were you employed by the Marconi company during the years 1904 to 1912?

Answer. I was manufacturing and general repairing wireless apparatus.

6. Question. Did your work during this period include the shipment of wireless apparatus of the Marconi company?

Answer. Yes.

• • • • • • •

[fol. 183] 43. Question. I call your attention to an article or device, marked for identification "Fleming valve receiver, E. A. Panabaker, commissioner." Did you ever see this article or device before, and if so, about when and where did you first see it?

Answer. This tuner was received by me from England in October, 1910.

44. Question. Where were you located in October, 1910, when you say this tuner was received by you from England?

Answer. At 125 Front Street, is my best recollection of this.

45. Question. And at that time the shop of the Marconi company was located at 125 Front Street?

Answer. 125 Front Street.

46. Question. And you received this tuner on behalf of the Marconi company?

Answer. Yes.

47. Question. This tuner is marked as follows: "Marconi Wireless Telegraph Company of America. No. 5015. New [fol. 184] York, U. S. A. Pat. No. 803,684." Do you know when that marking was placed upon this tuner? And if so, please give the time or the approximate time it was placed thereon and under what circumstances.

Answer. The tuner, when received by me in the early part of October, I had orders from the main office to have the name plate changed from Marconi Wireless Telegraph Co. of London (Ltd.), to the Marconi Wireless Telegraph Co. of America. I had this tuner taken to an engraver and had the new name engraved upon it.

48. Question. Did you also have the patent markings referred to engraved upon the tuner?

Answer. Yes.

49. Question. What are the parts of this tuner on which I have my hand at this present time?

Answer. The part which you have your hand on is known as an Ediswan bayonet socket for the reception of the Fleming oscillating valve.

50. Question. When this tuner was received from England, was it accompanied by any of the valves referred to in your last answer?

Answer. Yes; to the best of my knowledge there were six 12-volt valves accompanying this tuner.

51. Question. Do you know where such valves are now?

Answer. No.

52. Question. Was this tuner shipped by the plaintiff to anyone at any time to your knowledge?

Answer. Yes.

53. Question. To whom and when was it shipped?

Answer. On October 25, or thereabouts, 1910, I was given orders to ship this tuner to the U. S. S. *Louisiana* at the navy yard at Norfolk, Va., by express.

54. Question. What did you have to do with the shipping of this tuner to the *Louisiana* at the Norfolk Navy Yard, and how do you fix the date when it was shipped?

Answer. From the records in my shipping memorandum book of that date.

55. Question. Please look at the book now handed you and state what that book is?

Answer. This is shipping memorandum book of the Marconi Wireless Telegraph Co. of America.

56. Question. Please read on the record anything you find in the shipping memorandum book of the Marconi company relating to the shipping of the tuner No. 5015 to the U. S. S. *Louisiana* at the Norfolk Navy Yard.

Answer. "No. B 638. Original. Oct., 1910.

"Marconi Wireless Telegraph Company of America.

"Shipping order.

"Marconi W. T. Co. To Neil McIntyre,

"U. S. S. *Louisiana*, Norfolk Navy Yard.

"We have this day forwarded to you, carriage, the following goods per ——, Norfolk, Va.

"Kindly sign and return on receipt of goods.

1 inductance #710.

2 Witherbee batteries.

[fol. 185] 2 tungsten 12-volt valves.

1 pr. high-resistance phones.

1 Marconi disk condenser.

1 valve C. C. receiver #5015.

"Herschaft & Adams. X.

"Prepaid.

"Returned Oct. 31, 10."

57. Question. Will you please remove the shipping order B638 which you have just read on the record from the shipping order book?

(Witness removes the shipping order.)

58. Question. I notice that this shipping order does not bear the day of the month of October, 1910. How, then, do you know that this tuner referred to in the order was shipped to the Norfolk Navy Yard about October 25, 1910?

Answer. From the shipping order B637 of October 24, 1910, and also from the shipping order B639 of October 26, 1910—the one previous and the one following order B638.

59. Question. I notice that shipping order is addressed care of Neil McIntyre. Who was Mr. McIntyre and where is he now, if you know?

Answer. Mr. McIntyre at that time was in charge as operator of the Marconi wireless telegraph station, Virginia Beach, Va., and was told to carry on these tests aboard the U. S. S. *Louisiana* on account of its close proximity to the Norfolk Navy Yard and also his ability to work the valve receiver. Mr. McIntyre is dead.

60. Question. I notice that one of the items on this order reads "2 tungsten 12-volt valves." Will you please state if you know what that item refers to.

Answer. These were two incandescent bulbs with a metal band on the interior of the bulb. I have one here and which I produce, and from same is attached a small piece of platinum wire which penetrates the glass bulb and sealed and from thence a flexible lead.

61. Question. You mean by your last answer that the two tungsten 12-volt valves referred to in shipping order B638

were similar to the valves which you produced in answer to the last question?

* * * * * * *

Answer. Yes.

62. Question. When the tuner No. 5015 was sent to Norfolk Navy Yard was it accompanied by any valves; and, if so, what kind of valves?

Answer. Yes; two 12-volt tungsten valves, as heretofore described by me.

63. Question. To what part of the apparatus of tuner No. 5015 was the wire lead of the valves, above referred to, attached?

Answer. To the small upright rubber insulating post in connection with the circuit.

64. Question. I notice on the shipping order B638 "2 Witherbee batteries." To what does that item refer?

Answer. These batteries were used to light the bulb.

65. Question. Did these batteries accompany the tuner No. 5015 when sent to Norfolk Navy Yard?

Answer. Yes.

[fol. 186] 66. Question. In whose handwriting is shipping order B638, if you know?

Answer. Mr. E. M. Smith and my own—the words "Returned Oct. 31, 10," is my own handwriting.

67. Question. Is Mr. Smith connected with the Marconi company at present?

Answer. Mr. Smith severed his connection with the Marconi company somewheres around 1915.

68. Question. Will you please explain that part of the shipping order "Returned Oct. 31, 10," which you say is in your handwriting?

Answer. This was merely a notation by me showing return of the apparatus and acted as a credit against same.

Mr. Cosgrove. Plaintiff's counsel offers in evidence the valve tuner No. 5015, and requests that the same be marked "Plaintiff's Exhibit No. 28, Fleming valve receiver"; also the valve produced by the witness, and the same is marked "Plaintiff's Exhibit No. 29, Fleming valve"; also the shipping order B638, referred to by the witness, and the same is marked "Plaintiff's Exhibit 30, shipping order."

* * * * * * *

69. Question. Do you know where the valves are which you say accompanied plaintiff's Exhibit No. 28 when it was shipped to the Norfolk Navy Yard?

Answer. No; as the life of these valves are of very short duration and require constant new ones as the old ones burn out, and therefore are thrown away when of no further use.

70. Question. Do you know whether this Exhibit No. 28, Fleming valve receiver or tuner, was installed on any vessel; and if so, what vessel and about when the installation took place?

Answer. Somewhere around 1913 this particular valve receiver was installed on the steam yacht *Aloha* for the reception of long waves or news service, and was removed when a new installation was reinstalled on October 29, 1914, as our records show.

71. Question. I notice that shipping order B638, plaintiff's Exhibit 30, contains an item, "1 valve C. C. receiver #5015." State, if you know, what the letters C. C. refer to.

Answer. The initials C. C. stands for Cape Cod station, and the purpose of that station was to transmit long-distance messages and service news.

72. Question. What relation did this Fleming valve receiver Exhibit No. 28 have to the Cape Cod station, if you know?

Answer. This tuner was designed for the reception of the waves transmitted by Cape Cod and Poldhu.

* * * * * * *

73. Question. Do you know whether plaintiff's Exhibit No. 28, Fleming valve receiver or tuner, or one similar to it, was used at Cape Cod station?

[fol. 187] Answer. Yes.

* * * * * * *

74. Question. How do you know that such a receiver as plaintiff's Exhibit No. 28 was used at Cape Cod?

Answer. This tuner, upon its return from the steamship *Louisiana*, was sent by me to Cape Cod station, South Wellfleet Mass., as directed by my superiors.

Cross-examination.

By Mr. Workman:

* * * * * * *

71. Cross-question. Is it true that you have been continuously employed by the plaintiff company since June, 1904?

Answer. Yes.

72. Cross-question. And always in the same capacity?

Answer. Yes; in the mechanical department.

73. Cross-question. You were not superintendent or acting superintendent when you first entered their employ, were you?

Answer. No; as foreman.

74. Cross-question. You started work as foreman and then was promoted to superintendent or acting superintendent?

Answer. Yes; as the firm got larger.

75. Cross-question. And it has always been in mechanical work that you have been employed, has it?

Answer. Yes.

76. Cross-question. Just what sort of things did you do as foreman engaged on mechanical work?

Answer. Upon receiving orders from my superiors I manufactured and carried on experimental work and also shipped apparatus to different parts of the country to our stations.

77. Cross-question. Did you know anything about instruments or apparatus for wireless telegraphy before you came with the plaintiff company?

Answer. I was employed in the telegraph instrument line by J. H. Bunell Co. previous to my employment by the Marconi Wireless Telegraph Co.

78. Cross-question. In that line with Bunell, or work with Bunell Co., your work was with ordinary wire-transmission telegraph apparatus, wasn't it?

Answer. Yes.

79. Cross-question. You have gained all your knowledge and experience with wireless telegraph apparatus from your employment in the Marconi company, have you not?

Answer. Yes.

* * * * * * *

81. Cross-question. Can you state when it was you were promoted to superintendent or acting superintendent in the plaintiff company?

[fol. 188] Answer. This was not an official notification from my superiors, but took place naturally as the firm grew and we were compelled to employ more help.

82. Cross-question. Well, but you have not said when this took place; that is, when you became acting — or superintendent?

Answer. I can not give the dates when I began to receive correspondence with the name superintendent attached.

83. Cross-question. I don't suppose you were superintendent or acting superintendent in the first year or two of your employ in the plaintiff company, were you?

Answer. No.

84. Cross-question. And then some time later you had the work of superintendent, and I would like to know if you can give me some idea when you first began to act as superintendent?

Answer. Yes; when Mr. Sammis took over the duties as chief engineer, the dates of which I am rather hazy on at present.

85. Cross-question. Give us as near an approximation of the date as you can from your best recollection?

Answer. That was somewhere in 1907 or 1908, to the best of my recollection.

86. Cross-question. Were you ever employed as shipping clerk?

Answer. No; only as far as the shipping of apparatus of the Marconi Wireless Telegraph Co.

87. Cross-question. Were you ever employed as packer?

Answer. No; but I also did this work in the early days of the Marconi Telegraph Co.

88. Cross-question. Were you ever employed by the plaintiff company as invoice clerk to keep shipping records?

Answer. Only as far as the apparatus which left the works of the company.

89. Cross-question. Then you both attended to constructing the instrument and entering up their shipment books, did you?

Answer. Yes; and also Mr. Sammis assisted me in looking after the records.

90. Cross-question. And you put the apparatus to be shipped in their shipping cases, too, I suppose?

Answer. Yes.

91. Cross-question. Is it usual with the plaintiff company, so far as you know, to have their instrument makers act as shipping clerk, and packers?

Answer. At the time of my beginning of employment with the Marconi Wireless Telegraph Co. this was necessary, as wireless telegraph transmission was in its infancy, and did not employ sufficient help, as same was not needed.

92. Cross-question. You did not keep shipping books or attend to packing after you acted as superintendent from 1908 on, did you?

Answer. Yes; I kept in touch with all parts of the factory output and instruments and also their records.

93. Cross-question. And at the same time visited ships and acted as inspector?

Answer. Yes. As I heretofore stated, the firm was then small and was not a very big job to attend to.

94. Cross-question. How was it, then, that you did not make the entries in the shipping book relating to this tuner, [fol. 189] plaintiff's Exhibit 28, that you say is referred to on the shipping order B638, plaintiff's Exhibit 30?

Answer. Mr. E. M. Smith was employed in the early part of 1909 as a mechanic and also to help to attend to the clerical work with me.

95. Cross-question. This shipping order B638, plaintiff's Exhibit No. 30, was, as I understand it, not made out by you?

Answer. No: but a notation on the bottom of same of the return of the valve receiver was made by me, but other orders in the book are in my handwriting.

96. Cross-question. You infer that the items mentioned on this shipping order were sent on October 25, 1910, the date not appearing on the order, from the fact that the preceding order was dated October 24 and the following order October 26, 1910?

Answer. To the best of my knowledge, yes; from the *the* records.

97. Cross-question. Why was this tuner, defendant's Exhibit 28, returned so soon from Neil McIntyre?

Answer. I do not know, as I was not informed of the conditions or reasons why this was returned, as this was a matter in the hands of my superiors.

98. Cross-question. What does this date "Returned October 31, 10," which you say is in your handwriting—does that mean the date you received it back?

Answer. That is the date on which this tuner was returned.

99. Cross-question. Did you unpack it?

Answer. That is a question I can not answer.

100. Cross-question. And how did you know it was received back on the date noted on the bill?

Answer. That would not mean necessarily that I did unpack it personally, but still make a record of same as it was turned over to me.

101. Cross-question. Then that date means that that was the date it was turned over to you, doesn't it?

Answer. Yes.

102. Cross-question. You did not personally check off each of these items on that bill when they were sent, I suppose?

Answer. Yes; I did personally.

103. Cross-question. And you know that each one of these items mentioned on that bill was the shipping box and you saw the box sealed up with them in?

Answer. Yes.

104. Cross-question. And the bulbs, or whatever they were, were in the sockets when it was shipped?

Answer. No; these were packed in a separate container invariably in cotton batting to prevent jarring or breaking of the tungsten filaments.

105. Cross-question. How many of these bulbs came with the tuner when it was received from England?

Answer. To the best of my knowledge, there were six 12-volt valves received with this tuner.

106. Cross-question. Was it tested by the Marconi company before it was shipped to Neil McIntyre?

Answer. That I do not know.

[fols. 190-191] 107. Cross-question. When was it tested on the yacht *Aloha?*

Answer. It was not merely tested but was installed as a part of the apparatus for the reception of news service in conjunction with the other receivers.

108. Cross-question. And you do not know whether it was ever used or not on this yacht?

Answer. Not to my knowledge, as I did not have anything to do with the operating end.

109. Cross-question. Did you ever actually see it on the yacht?

Answer. Yes; upon one of my visits to this yacht, at the foot of East Twenty-third Street.

110. Cross-question. Do you know who owns this yacht?

Answer. I believe Colonel James is the owner of this yacht.

111. Cross-question. At any rate it was not a Government vessel?

Answer. No.

112. Cross-question. When was it you saw it on the yacht, what year?

Answer. The date I can not give you; it was sometime in 1914.

113. Cross-question. Of course the bulbs that were then on it were not the bulbs you received from England?

Answer. No.

114. Cross-question. Nor those you say were sent to Neil McIntyre at Norfolk?

Answer. No; they were not the bulbs.

115. Cross-question. Where did you get this bulb with a piece of covered wire attached to one side of it that you produced in your direct examination?

Answer. This was taken from the works at 25 Elm Street, a number of which we still retain in stock.

116. Cross-question. When was it made, do you know?

Answer. The present valve?

117. Cross-question. This one you produced?

Answer. I can not give the exact date at present without looking up my records.

118. Cross-question. Do you know whether it was made one or two years ago, don't you?

Answer. I know this valve was made more than four years ago, that is the present type shown here.

119. Cross-question. This one that you produced is not the type you are now using is it?

Answer. No. At present we use a crystal detector on all our tuners.

120. Cross-question. This bulb that you produced here is a crude clumsy sort of a device, is it not, with this thread going around the outside of it?

Answer. The thread going around the outside of the bulb is to act as a support for the flexible copper lead so as not to break the delicate connection coming through the glass.

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[fol. 192] "By Mr. Cosgrove: Plaintiff's Counsel offers in evidence the following:

"Printed copy of Marconi British Patent No. 7777 of 1900, and requests that the same be marked Plaintiff's Exhibit No. 34, Marconi British Patent.

"Copy of the decision or judgment of Mr. Justice Eve in the English High Court of Justice in the suit of G. Marconi Wireless Telegraph Company vs. The Helsby Wireless Telegraph Company, Limited, for the infringe-[fol. 193] ment of the Marconi British patent #7777 of 1900, and requests that the same be marked Plaintiff's Exhibit #35, Justice Eves Judgment.

"Copy of Judgment of the Civil Tribunal of the Seine in the case of Marconi Wireless Telegraph Company, Limited, against the Society Gen. des Transports Maritime, brought for the infringement of the Marconi French patent #305,060, (corresponding to British patent No. 7777) and requests that the same be marked Plaintiff's Exhibit #36, French judgment.

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"Plaintiff also gives notice that upon the hearing of this case, it will rely upon the following:

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"Decision of Judge Veeder of the United States District Court for the Eastern District of New York, dated March 17, 1914, sustaining the validity of the Lodge patent No. 609,154, and the Marconi patent No. 763,772, and holding it infringed by the National Electric Signal Company apparatus.

"Decision and order of Judge Veeder of the United States District Court for the Eastern District of New York, dated October 15, 1914, sustaining the Lodge patent No. 609,154, and Marconi patent No. 763,772, and granting a preliminary injunction restraining the Atlantic Communication Company apparatus from infringing upon said patents.

"Decision and order of Judge Hough of the United States District Court for the Southern District of New York, dated November 12, 1914, sustaining the Lodge patent No. 609.154, and Marconi patent in suit No. 763,722, and granting a preliminary injunction restraining the infringe-

ment thereof by the apparatus of the DeForest Radio Telephone and Telegraph Company, and the decision of the Court of Appeals of the Second Circuit affirming the said decision of Judge Hough.

"Decision of Judge Mayer, United States District Court for the Southern District of New York, dated September 20, 1916, sustaining the validity of the Fleming patent in suit No. 803,684, and holding it infringed by the audion apparatus of the DeForest Radio Telephone & Telegraph Company.

"Plaintiff's Counsel also offers in evidence the following:

"Printed copy 'Specifications for Wireless Telegraph Apparatus sets,' issued by the Navy Department May 10, 1910, No. 16-T-5, with particular reference to pages 1, 3, [fol. 194] 5, 8, 9, 10 and 12 thereof, and requests that the same be marked 'Plaintiff's Exhibit #37, Navy Wireless Specifications #16-T-5.'

"Printed copy 'Navy Department specifications Radio sets for Ship Installations January 10, 1913, #16-R-1,' with particular reference to pages 1, 2, 17, 19, 20, 25 and 30, and requests that the same be marked Plaintiff's Exhibit #38, Navy Department Wireless Specification #16-R-1.

"Printed copy 'Navy Department specifications Radio sets for ship and shore stations #16-R-1-A December 1, 1915,' with particular reference to pages 1, 2, 5, 16, 17 and 22, and requests that the same be marked Plaintiff's Exhibit #39, Navy Wireless Specification #16-R1A.

"Printed copy 'Navy Department Specifications. Radio apparatus, receiving #16-R-2, January 3, 1916,' with particular reference to pages 1, 4, 5, 6 and 7, and requests that the same be marked Plaintiff's Exhibit #40, Navy Wireless Specifications #16-R-2.

"Typewritten copy 'Specifications for portable wireless telegraph sets' proposed by the United States Navy, with blue prints 1815-L, dated 9-22-10, of the Bureau of Steam Engineering of the Navy Department attached to said specification and request that the same be marked Plaintiff's Exhibit #41, Navy Specifications for Portable Wireless Sets.

"Typewritten copy 'General specification, No. 547. (September 13, 1910)' of the Army Signal Corps for 'Wireless Telegraph Sets 2 k. w. quenched singing spark type'

and requests that the same be marked Plaintiff's Exhibit #42, Army Wireless Specification #547.

"Typewritten copy 'General Specification #566 (January 27, 1912) wireless Telegraph Station Equipment,' of the Army Signal Corps, and requests that the same be marked Plaintiff's Exhibit #43, Army Wireless specification #566.

"Typewritten copy of Army Signal Corps 'Specification for 2-kilowatts Radio Field Wagon Set (February 19, 1916),' and requests that the same be marked Plaintiff's Exhibit #44, Army Specification for Radio Field Wagon Set.

"Counsel also offers in evidence certified copies of the following contracts for wireless telegraph apparatus sold to and used by the United States:

"Garwood Electric Company with the United States Navy, No. 14,811, dated May 1st, 1911, for transmitting and receiving wireless sets under Navy Department specification #16-T-5, to be delivered to the Brooklyn Navy Yard for the U. S. S. *Jupiter, Neptune, Ammen, Trippe, Monahan, Walker* and *Patterson*, and requests that the same be marked Plaintiff's Exhibit #45, Garwood contract of May, 1911.

"Telefunken Wireless Telegraph Company of the United States with the United States Navy #144, dated September 20, 1911, for transmitting and receiving wireless sets, and requests that the same be marked Plaintiff's Exhibit #46, Telefunken contract of September, 1911.

"Atlantic Communication Company with the United States Army Signal Corps No. 608, dated September 29, 1913, for a transmitting and receiving wireless set under Army Specifications #566, Jan. 27, 1912, and requests that [fol. 195] the same be marked Plaintiff's Exhibit #47, Atlantic Communication Company Army contract of September 29, 1913.

"Atlantic Communication Company with the United States Navy, #89, dated August 5, 1913, for 1-k.w. Telefunken Compass Radio outfit complete, to be delivered to the Brooklyn Navy Yard, and requests that the same be marked Plaintiff's Exhibit #48, Atlantic Communication Company Navy contract of August 5, 1913.

"National Electrical Supply Company with the Signal Corps, United States Army, dated April 26, 1910, for 'one (1) field wireless pack set two-trunk type,' under Signal

Corps Specification #410, revised to bear serial number 70, to be delivered to the Brooklyn Navy Yard, and requests that the same be marked Plaintiff's Exhibit #49, National Electrical Supply Company Army contract of April 26, 1910.

"National Electrical Supply Company with U. S. Signal Corps, dated May 16, 1911, for Field Wireless Pack Sets, and requests the same be marked Plaintiff's Exhibit No. 50, National Electrical Supply Company Army Contract of May 16, 1911.

"National Electrical Supply Company with the United States Army #619, dated January 23, 1914, for 'Wireless Transmitting and Receiving Sets,' and requests that the same be marked Plaintiff's Exhibit #51, National Electric Supply Company Army contract of January 14, 1914.

"National Electrical Supply Company with the Navy Department #19,575, dated September 9, 1913, for fifteen ½-k. w. 500-cycle quenched gap sets, etc., to be delivered at the Washington Navy Yard, and requests that the same be marked Plaintiff's Exhibit #52, National Electric Supply Company Navy contract of September 9, 1913.

"Foote, Pierson and Company with the United States Army Signal Corps, dated June 27, 1910, for eight Field Wireless Pack Sets complete under Signal Corps Wireless Specification #410, number D revised, and requests that the same be marked Plaintiff's Exhibit #53, Foote, Pierson and Company Army contract of June 27, 1910.

"North American Wireless Corporation and the United States Army Signal Corps, #445, dated October 24, 1910, for one wireless telegraph set complete including crystal detector, under Signal Corps Specifications #547 and 403-A, and requests that the same be marked Plaintiff's Exhibit #54, North American Wireless Corporation Army contract of October 24, 1910.

"Wireless Improvement Company and the United States Navy Department #415, dated June 5, 1913, for one 5-k. w. high frequency quenched gap radio transmitting set complete, etc., under wireless specifications #16-R-1, to be delivered at the U. S. Naval Radio Station, Radio, Va., and requests that the same be marked Plaintiff's Exhibit #55, Wireless Improvement Company Navy contract of June 5, 1913.

"Clapp-Eastham Company with the United States Navy Department, 2 radio sets complete, except receiving appa-

ratus, etc., for Submarines E-1 and E-2, dated October 14, 1912, and requests that the same be marked Plaintiff's Exhibit #56, Clapp-Eastham Company Navy Contract.

[fol. 196] "Fritz Lowenstein with the United States Navy Department No. 14,746, dated April 22, 1911, for 500-cycle motor generator sets complete, except antenna, under specifications #16-T-5, to be delivered at the Brooklyn Navy Yard and requests that the same be marked Plaintiff's Exhibit #57, Lowenstein Navy contract of April 22, 1911.

"Fritz Lowenstein with the United States Navy Department dated November 1, 1913, for four 5-k. w. Radio sets under Navy Wireless Specification #16-R-1 to be delivered at the Brooklyn Navy Yard, and requests that the same be marked Plaintiff's Exhibit #58, Lowenstein Navy contract of November 1, 1913.

"Wireless Specialty Apparatus Company with the United States Signal Corps, dated December 7, 1911, for two wireless receiving sets type 1-P-76, and requests that the same be marked Plaintiff's Exhibit #59, Wireless Specialty Apparatus Company Army contract dated December 7, 1911.

"Wireless Specialty Apparatus Company and the United States Navy Department #133, dated September 21, 1912, for 25-k. w. 500 cycle quenched gap radio sets under Navy Wireless specification #16-T-5, and requests that the same be marked Plaintiff's Exhibit #60, Wireless Specialty Apparatus Company Navy contract dated September 21, 1912.

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"Wireless Specialty Apparatus Company with the United States Navy Department #170, dated October 14, 1912, for wireless receiving sets improved type I-P-76, containing perikon and pyron detectors, to be delivered at the Brooklyn Navy Yard, and requests that the same be marked Plaintiff's Exhibit #62, Wireless Specialty Apparatus contract of October 14, 1912.

"Wireless Specialty Apparatus Company with the United States Navy Department No. 19,882, dated Nov. 18, 1913, for receiving sets type I-P-76, 1912 series and I-P-76, 1914 series, and requests that the same be marked Plaintiff's Exhibit #63, Wireless Specialty Apparatus contract of Nov. 18, 1913.

"Federal Telegraph Company with the United States Navy Department #100 dated September 1, 1911, for one

2-k. w. quenched gap wireless telegraph set complete to be delivered at Mare Island Navy Yard, California, and requests that the same be marked Plaintiff's Exhibit #64, Federal Telegraph Company contract of September 1, 1911.

"Federal Telegraph Company with the United States #1948, dated June 30, 1913, for high powered radio station at United States Naval Reservation San Pablo Site, Camito, Canal Zone, and requests that the same be marked Plaintiff's Exhibit #65, Federal Telegraph Company U. S. contract, dated June 30, 1913.

"Federal Telegraph Company with the United States, dated June 11, 1914, supplemental agreement to contract of June 30, 1913, for the installation of a radio station at [fol. 197] San Pablo Site, Canal Zone, and requests that the same be marked Plaintiff's Exhibit #66, Federal Telegraph Company United States contract of June 11, 1914.

"Federal Telegraph Company with the United States Navy Department #269, dated April 6, 1914, for arc radio sets to be delivered at the Washington Navy Yard for Point Isabel, Texas, Guantanamo, Cuba, and Boston, Mass., and requests that the same be marked Plaintiff's Exhibit #67, Federal Telegraph Company Navy contract of April 6, 1914

"Federal Telegraph Company with the United States Navy, No. 242, dated May 6, 1915, for 30 k. w. Arc Transmitters, etc., under Navy specifications 16-R-1, to be delivered to Mare Island Navy Yard, and requests that the same be marked Plaintiff's Exhibit #68, Federal Telegraph Company contract of May 6, 1915.

"Kilbourne and Clark Manufacturing Company with the United States Navy Department #225, dated January 31, 1914, for five 5 k. w. radio sets complete for ship installation under Navy Wireless specification #16-R-1, to be delivered at Navy Yard, Mare Island, California, and Brooklyn Navy Yard, N. Y., and requests that the same be marked Plaintiff's Exhibit #69, Kilbourne and Clark Mfg. Co. Navy contract of January 31, 1914.

"Emil J. Simon and the United States Navy Department No. 24,605, dated September 2, 1915, for twenty-five ½ k. w. radio transmitting sets, etc., to be delivered at the Brooklyn Navy Yard, and requests that the same be marked Plaintiff's Exhibit #70, Simon Navy contract of September 2, 1915.

"Radio Telephone and Telegraph Company and the United States Navy Department No. 20,437, dated March 5, 1914, for radio sets under Navy wireless specification #16-R-1, to be delivered at the Brooklyn Navy Yard, and requests that the same be marked Plaintiff's Exhibit #71, Radio Telephone and Telegraph Company Navy contract of March 5, 1914.

"Radio Telephone and Telegraph Company and the United States Navy Department No. 336 dated January 12, 1914, for audion amplifiers and double bulbs for the same, etc., to be delivered at the Brooklyn Navy Yard, and requests that the same be marked Plaintiff's Exhibit #72, Radio Telephone and Telegraph Company Navy contract of January 12, 1914.

"Radio Telephone and Telegraph Company and the United States Navy Department #534, dated June 11, 1914, for audion amplifiers and double bulbs with Hudson filaments to be delivered at the Brooklyn Navy Yard, and requests that the same be marked Plaintiff's Exhibit #73, Radio Telephone and Telegraph Company Navy contract of June 11, 1914.

"Radio Telephone and Telegraph Company with the United States Navy Department No. 315, dated June 27, 1914, for ultra audion detectors Hudson filament double bulbs, receiving cabinets, etc., to be delivered at the Washington Navy Yard and requests that the same be marked Plaintiff's Exhibit #74, Radio Telephone and Telegraph Company Navy contract of June 27, 1914.

"Radio Telephone and Telegraph Company and United States Navy Department No. 46, dated July 27, 1914, for generator audion sets and bulbs to be delivered at the Wash- [fols. 198-199] ington Navy Yard, and requests that the same be marked Plaintiff's Exhibit #75, Radio Telephone and Telegraph Company Navy contract of July 27, 1914.

"DeForest Radio Telephone and Telegraph Company with United States Navy Department #508 dated June 28, 1916, for Hudson filament 6-volt bulbs with double grid, to be delivered at the Washington Navy Yard, and requests that the same be marked Plaintiff's Exhibit #76, DeForest Radio Telephone and Telegraph contract of June 28, 1916.

"Plaintiff's Counsel also offers in evidence:

"Certified copy of British Letters Patent No. 24,850 of 1904 filed Nov. 16, 1904, and requests that the same be

marked Plaintiff's Exhibit #77, Fleming British Patent #24,850.

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[fol. 200] *Deposition of William A. Graham, for claimant, taken at New York, N. Y., on the 27th, 28th, and 29th days of June, A. D. 1917*

Claimant's counsel, James J. Cosgrove and John W. Peters; defendant's counsel, Henry C. Workman.

William A. Graham deposed and said that his name is William A. Graham; that his occupation is that of radio engineer, with the Marconi Wireless Telegraph Co.; that he is 30 years of age; that his place of residence is Roselle Park, N. J.

And thereupon the said William A. Graham was examined by the counsel for the plaintiff, and in answer to interrogatories testified as follows:

Direct examination.

By Mr. Peters:

1. Question. Have you heretofore been in the service of the United States Navy? And if so, please state during what period of time and in what capacity.

[fol. 201] Answer. I entered the naval service in January, 1904, and served continuously until September, 1916. During the period of years mentioned above I served in the various grades of electrician and chief electrician in the radio branch of the service. From February, 1917, until May, 1917, I served as expert radio aid, United States naval service.

2. Question. Please explain what opportunity you had during your service in the Navy from June, 1910, down to September, 1916, when you left, to become familiar with the wireless-telegraph apparatus installed and used by the Navy.

Answer. During the period from June, 1910, to 1916 I had charge of the ship installation of wireless apparatus on several ships. I was also chief electrician in charge of the United States Navy Radio Station at San Juan, Porto Rico; also at the radio station, Sayville, Long Island, and

at the naval radio laboratory, Bureau of Standards. During my service at these various places I became familiar with a great many types of apparatus used by the Navy.

3. Question. Name some of the types which, to your knowledge, were installed and used by the Navy during the period beginning with July, 1910, and ending with September, 1916, when you left the Navy.

Answer. Of transmitting apparatus, I have knowledge of the installation and operation of the Telefunken, Marconi, National Electric Supply Co., Federal Telegraph Co., Wireless Improvement Co.; of receiving apparatus, the Wireless Specialty Apparatus Co., Telefunken, Marconi, and De Forest Co.'s apparatus, the latter including types of audion, ultra audion, and amplifier apparatus.

4. Question. To your knowledge, was there any use by the Navy during this period of Lowenstein apparatus?

Answer. While in the naval service I saw a Lowenstein transmitter in operation at the Brooklyn Navy Yard.

5. Question. About when was this and under what circumstances did you see it?

Answer. I saw the Lowenstein transmitter during the year 1914 on the occasion of an official visit to the New York Navy Yard.

6. Question. Was this Lowenstein set in use when you saw it?

Answer. It was being operated by the personnel attached to the station in the usual course of the day's business.

6a. Question. What can you say as to whether or not it was installed and used by the Navy subsequent to June, 1910?

Answer. When I saw this Lowenstein set it was in practical operation; in order to be in practical operation during the year 1914, it follows that it was installed prior to the date which I saw it in operation.

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7. Question. When you saw it in 1914, was it new apparatus recently installed, or was it an old set that had been used for several years?

* * * * * * *

Answer. It appeared to be a new set.

8. Question. I show you a volume entitled "Manual of Wireless Telegraphy (Radio) for the Use of Naval Elec-

[fol. 202] tricians, 1915," by Commander S. S. Robison, U. S. Navy. What, if anything, do you know regarding the distribution and use of this manual in the Navy?

Answer. I recognize the volume as one issued by the Navy Department and distributed to naval wireless telegraph stations on shore and on ship. As I remember, several copies were issued to each ship, one for use in the ship's library and another for use in the wireless office. On shore stations this volume was placed in the library and available for use by the personnel attached to the station.

9. Question. Reference to this volume indicates that it is a revision of earlier editions. What were the facts, if you know them, with regard to the issuance of earlier editions of this publication?

Answer. I have seen earlier editions of the volume in question, and the distribution of these volumes followed the method described for the 1915 volume.

10. Question. When, to your knowledge, was this particular edition marked "1915" issued and distributed?

Answer. I do not remember.

11. Question. Was it before you left the Navy?

Answer. I don't remember.

12. Question. I show you what purports to be an earlier edition of the same publication, having the same title and bearing a publication date 1913. What, if anything, do you know about the distribution and use of this volume by the Navy?

Answer. I recognize this volume as a copy of the publication issued to a wireless station to which I was at one time attached. The volume was for use in familiarizing the personnel attached to the station with the various types of apparatus described therein.

Mr. Peters: I offer in evidence the two volumes referred to by the witness and request that they be marked "Plaintiff's Exhibit, Navy manuals, 1913 and 1915, No. 78."

13. Question. I call your attention to plaintiff's Exhibit No. 46, a certified copy of a contract between the Telefunken Wireless Telegraph Co. and the United States, particularly to the description of the Telefunken apparatus therein, including the circuit drawing of the Telefunken apparatus, and ask you to examine the same and state what, if anything, you know with reference to the use of Tele-

funken apparatus of the type shown in this contract by the Navy Department subsequent to June, 1910?

Answer. While stationed at San Juan, Porto Rico, in the year 1914, I installed at the naval radio station there a Telefunken transmitter of a type similar to that shown in the wiring diagram of this exhibit. On the occasion of a visit to the U. S. S. *Louisiana* in the same year I saw a Telefunken transmitter and receiver of a type similar to that shown in this diagram installed on that ship.

14. Question. What do you know with respect to the date when this installation on the *Louisiana* was made?

Answer. I do not remember the exact date, but on the occasion of my visit to the *Louisiana* mentioned above the installation I have referred to was in progress.

15. Question. The contract referred to refers to two types of Telefunken receiver, known as E5 and E4, respectively. Did you see both of these types at San Juan or on the *Louisiana?*

[fol. 203] Answer. At San Juan only a transmitting apparatus was installed. On the *Louisiana* I saw two types of Telefunken receivers—the E4 and E5.

16. Question. Please describe the Telefunken apparatus you saw on the *Louisiana*, referring to a drawing of the same, if you have prepared and can produce the same?

*   *   *   *   *   *   *   *

Answer. The Telefunken apparatus with which I am familiar is shown diagrammatically in the sketch which I produce. (See plaintiff's Exhibit No. 79.) The transmitter was connected to the antenna *f* through the lead A and contact 1. The transmitting apparatus consisted of the antenna loading coil *g*, antenna hortening condenser H (for use in transmitting short wave lengths only), the oscillation transformer *d* and *d'*, capacity *e*, quenched spark gap G, transformer *c*, key *b*, motor generator *a*, and earth connection E. The operation of this transmitter is as follows:

When the key *b* was depressed current from the alternator of the motor generator *a* flowed through the primary winding of the transformer *c*. The current generated in the secondary coil of the transformer *c* charged the capacity *e* through the primary of the oscillation transformer *d*. The capacity *e*, when fully charged, discharged through a circuit containing the quenched spark gap G and the pri-

mary of the oscillation transformer *d*. The variable contact 2 and 2[a] were provided for tuning the closed oscillating circuit *e*, G, 2[a], *d*, 2. Current impulses set up in the closed oscillating circuit described above produced similar currents in the open oscillating circuit *f*, A, *g*, H, *d'*, and E through the medium of the magnetic coupling of the oscillation transformer *d*, *d'*.

The Telefunken receiving apparatus, with which I am familiar, was connected to the antenna *f'*, A. The receiving apparatus was of two types—the E5 and the E4. The E5 type consisted of an oscillation transformer *j*, j^2, condenser *h*, earth B, variable condenser *h'*, detector T, stopping condenser j^3, and telephone receiver R. The antenna was connected to the primary coil of the oscillation transformer by means of the variable contact 2 to the earth E. The variable condenser *h* could by means of switching arrangements be connected either in parallel to the coil *j* or in series with the lead A. Impulses set up in the primary circuit just described were transferred to the closed oscillating circuit j^2, *h'*, 4 or 4[a], by means of the coupling between the two coils *j*, j^2. Currents or impulses in the closed oscillating circuit just described were rectified by means of the detector T and received by means of the telephone receiver R. The E4 type of receiver was similar to the E5, with the exception that no tuning condenser was provided in the closed oscillating circuit of the receiver. However, rough tuning could be accomplished by varying the inductance j^2 by means of the variable contact 4.

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[fol. 204] 17. Question. While in the Navy did you ever operate or see other Navy operators adjust and operate Telefunken apparatus of the type you have been describing?

Answer. I have operated the Telefunken transmitter, which I have described, and I have seen other operators operating the receiving apparatus, although I have never operated a Telefunken receiver myself.

18. Question. Please explain, both with respect to the transmitter and the receiver, each and all of the adjustments made by an operator in getting the apparatus ready to operate and in operating the same.

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Answer. In the practical operation of a transmitter a predetermined number of wave lengths were selected and the apparatus adjusted to give these wave lengths, as it was found expedient to vary the wave lengths of a transmitter from time to time. In adjusting the transmitter to these predetermined wave lengths the amount of inductance in the coils *d*, *d'*, and *g* was selected so as to give the proper wave lengths. In adjusting the transmitter to one of these wave lengths, the closed oscillating circuit *d*, G *c* was first adjusted to the desired wave length by means of the variable contact 2. This point on the coil *d* was then brought to a fixed point so that the variable contact 2 could be moved *to another position; but if at any future time it was desired* to send on the wave length to which the closed oscillating circuit had been adjusted, it would be only necessary to connect the variable contact 2 to this fixed point. Similarly other points on the coil *d* corresponding to the predetermined wave length could be connected in circuit by means of variable contact 2. The open oscillating circuit was then tuned with the closed oscillating circuit by varying the amount of inductance in the coils *d'* and *g*. Fixed amount of inductances in the coils *d'* and *g* were brought to fixed points to which the contacts 1^a and 1 could connect. The coupling between the circuits *d* and *d'* had to be adjusted separately for each wave length. In order to change the wave length of the transmitters, the variable contact 2 was connected with the fixed point corresponding to that wave length, the variable contacts 1^a and 1 in the open oscillating circuit were connected to the fixed points corresponding to that wave length, and the coupling *d*, *d'*, was varied until the maximum radiation was obtained.

In receiving a signal on the Telefunken receivers, it was necessary to tune the antenna to the wave length of the signal it was desired to receive. This was accomplished by varying the inductance and capacity in the circuit *j*, *h*, 2. The closed oscillating circuit of the receiver was then adjusted to the wave length of the primary circuit by varying the inductance and capacity j^2, h' of the circuit. Currents generated in this circuit were rectified by the detector T, and the rectified current flowing through the receiver R caused the diaphragm of that receiver to vibrate, producing sounds which were audible to the ear.

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[fol. 205] 19. Question. In receiving signals with the Telefunken type E4 receiver, shown in your drawing, what adjustments, if any, were made in the circuit j^2, 4, T, j^3?

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Answer. In the E4 type of receiver, the inductance of the coil j^2 was adjustable in increments permitting rough tuning of this secondary circuit.

20. Question. Was the oscillation transformer of the transmitting apparatus in the Telefunken apparatus at San Juan and on the *Louisiana* formed of two separate coils or was it a single coil? Please refer to your drawing and explain this point.

Answer. In the Telefunken type of transmitter, such as I have been describing, the oscillation transformer *d d'* consisted of a single coil, portions of which were common to both the closed oscillating circuit and the open radiating circuit forming what was commonly called a direct coupled circuit.

21. Question. You referred to varying the coupling of the closed oscillating and the radiating circuit of the Telefunken transmitter. How was that accomplished?

Answer. Varying the coupling in the coil in question was accomplished by varying the position of the common portion of the coil in reference to the total inductance between the points 1^a and 2^a, also by varying the mutual inductance between the coils *g*.

22. Question. Describe the Telefunken detector shown at T, in both the E5 and E4 receiver drawings.

Answer. The detector used with the Telefunken type of receiver was of the crystal type and was composed of iron pyrites. A metallic contact was made with the iron pyrite crystal. The detector was so designed that it was possible to vary this metal contact over the surface of the crystal.

23 Question. You mentioned tuning the closed oscillatory circuit of the Telefunken transmitter and also the tuning of the open radiating circuits. To what were these circuits tuned?

Answer. They were tuned to each other and to the wave length that it was desired to operate these transmitters.

24. Question. You also mentioned the tuning of the open primary circuit of the Telefunken receiver and the closed circuit of the receiver. To what were these circuits tuned?

Answer. The primary circuit of the receiver was tuned to the wave lengths of an incoming signal that it was desired to receive. The secondary circuit of the receiver was tuned to the primary circuit.

25. Question. You have stated that the capacity H shown in the antenna lead of the Telefunken transmitter was sometimes cut out or not used. Will you please indicate on the drawing the switch for cutting that capacity out?

Answer. I have done so and marked the switch S.

Mr. Peters. I offer in evidence the drawing referred to by the witness and ask that the same be marked "Plaintiff's Exhibit No. 79, drawing, Telefunken apparatus."

[fol. 206] 26. Question. You have stated that you have knowledge of National Electric Supply Co.'s apparatus installed and used by the Navy in the period beginning July, 1910, and ending September, 1916. In what year was this apparatus installed and where was it installed and used?

Answer. While I was attached to the U. S. S. *Georgia* as chief electrician from the latter part of 1912 to the early part of 1914, a portable field set, manufactured by the National Electric Supply Co. was furnished the vessel on which I was serving. This apparatus was contained in two trunks and could be set up and operated either on board ship or on shore. It was provided for use with landing parties.

27. Question. During the time you were attached to the S. S. *Georgia* did you set it up and use it?

Answer. On several occasions I set up and operated this set, once at the naval camp at Guantanamo Bay, Cuba, and another time on board ship at Vera Cruz, Mexico, for test with a vessel stationed at Tampico, Mexico, the object being to determine the reliability of the set to transmit great distances.

28. Question. Did you have a drawing made showing this National Electric Supply Co.'s apparatus?

Answer. I have prepared a drawing, showing diagrammatically the circuit connections for the portable set I have been discussing, and produce the same.

29. Question. Will you please describe this National Electric Supply Co. apparatus by reference to the drawing (P. Ex. 80) you have produced?

Answer. This apparatus consisted of a motor generator *a*, sending key *b*, transformer *c*, capacity *e*, quenched spark

gap G, oscillation transformer d, d', antenna A, and earth connection E. The receiving portion of this set consisted of an oscillation transformer j^1, j^2, shortening condenser h, detector T, stopping condenser j^o, and telephone receiver R. The transmitting and receiving apparatus were mounted together in a trunk; the motor generator was mounted alone in a small trunk.

30. Question. What provision if any was made in this apparatus for tuning the several circuits?

Answer. The transmitting portion of the apparatus was provided with an oscillation transformer having two coils d, d'—the amount of inductance of these coils and the value of the coupling between them could be varied so that it was possible to tune both the closed oscillating circuit and the open radiating circuit to any wave length in the range of the instrument. In the receiving portion of the apparatus an oscillation transformer j^1 j^2 was provided. The value of the inductance in the coils j^1 j^2 could be varied, also the coupling between these two coils. This made it possible to vary the wave length of the receiver over the entire range of the instrument.

31. Question. What provision was made for tuning or adjusting the time period of the closed or secondary circuit of the receiver?

Answer. The inductance of the coil j^2 could be varied by means of the contact 5, thus changing the time period of the circuit in question.

[fol. 207] 32. Question. Describe the detector supplied with this National Electric Supply Co. apparatus, shown at T on your drawing.

Answer. The detector supplied with this apparatus was of the crystal type known as galena. It consisted of a galena crystal and a fine-wire contact. The mounting of the fine wire was so designed that it could make contact with any part of the surface of the galena crystal. It was also possible to vary the pressure of this contact against the crystal.

33. Question. Was the oscillation transformer forming part of the transmitter of the apparatus you have just referred to formed of two separate independent coils or of a single coil? Please state what the facts were.

Answer. The oscillation transformer was composed of two separate coils without metallic connection between them, forming what was known as an inductive coupling.

34. Question. As I read the drawing you have produced, it shows but a single coil, a portion of which is included in the closed oscillatory circuit. If I am right in this, will you have your drawing corrected to show two independent coils?

Answer. I have corrected it in pencil and will have it inked in later.

35. Question. I call your attention to your twenty-ninth answer, in which in enumerating the elements of the receiver you omitted to mention an antenna. Was this omission intentional?

Answer. The omission was an oversight; it should have been included in my answer to Q. 29. The antenna of the portable set I have been describing was also a portable affair and was used for both transmitting and receiving.

36. Question. In the actual operation of this National Electric Supply Co.'s apparatus, what use was made of the means for tuning the several circuits of the apparatus referred to in your previous answers?

Answer. The tuning of the transmitting portion of the portable sets made it possible to select a wave length which the set operated at best. Also, if for any reason it was desired to send on a different wave length, change of wave length could be easily and rapidly accomplished. In tuning the receiver it was possible to pick up signals over considerable range of wave lengths.

37. Question. You have referred to the tuning of the closed oscillatory circuit forming a part of this transmitter. To what was this circuit tuned?

Answer. The closed oscillating circuit of the transmitter was tuned to the wave length that it was desired to transmit.

38. Question. How about the open radiating circuit? To what was that tuned?

Answer. The open radiating circuit was tuned to the closed oscillating circuit of this transmitter.

39. Question. To what were the circuits of the receiver tuned?

Answer. The primary or antenna circuit of the receiver was tuned to the wave length of the signal which it was desired to receive. The secondary circuit of the receiver was tuned to the primary circuit.

40. Question. What type of spark gap was used in this apparatus?

Answer. A quenched gap type was used.

[fol. 208] Mr. Peters. I offer the drawing as corrected and as described by the witness in evidence, and request that the same be marked "Plaintiff's Exhibit No. 80, drawing, National Electric Supply Co. apparatus."

* * * * * * *

41. Question. I show you plaintiff's Exhibit No. 57, being a certified copy of a contract between Fritz Lowenstein and the United States, and call your attention to the description of the transmitting apparatus contained therein and as shown in the annexed drawings, and particularly the drawings marked "T-8." Please examine this and state whether or not during your service in the Navy you saw apparatus of this type installed and in use; and if so, under what circumstances.

Answer. I recognize the sketch on sheet marked "*r*-4*s*" and "T-8" as the Lowenstein transmitter, which I saw on the occasion of an official visit to the New York Navy Yard station in the latter part of 1914.

42 Question. Was the Lowenstein transmitter referred to installed and in operative condition? If so, what can you say as to whether or not it had been installed subsequent to June, 1910?

Answer. The apparatus referred to was installed and in operation at the time I saw it, namely, the latter part of the year 1914.

43. Question. What can you say as to whether this particular set was installed at the navy yard prior or subsequent to June, 1910?

Answer. I do not know the date of installation of this apparatus, but do know that it was in operation during the latter part of 1914.

44. Question. Just where in the navy yard was it installed and in operation?

Answer. It was in operation at the radio station building, near the navy-yard gate, at the time I saw it.

45. Question. Please describe this transmitter briefly, referring, if necessary, to drawing T-8 (see P. Ex. No. 57), and applying reference numerals to this drawing if necessary.

Answer. The characteristic features of this transmitter were the wave changing switch A, the combination inductive and conductive oscillation transformer B, and the quenched

gap. The wave changing switch consisted of a number of points which were connected to various points on the coupling and loading inductances and an arm containing contacts which connected to these fixed points. Quick change control was effected by selecting the points to which the switch arm connected. The quenched spark gap was notable because of its design. It consisted of a number of concentric cylinders arranged on a circular piece of insulating material, with a switch to control or select the number of individual gaps that it was desired to use in circuit. An air blast from a fan kept these gaps cool. This fan is shown at C.

46. Question. What are the other elements of the circuit comprising the element marked on this drawing "primary condenser"?

Answer I do not understand the question.

47. Question. Did this Lowenstein transmitter you saw comprise an open radiating circuit? If so, will you please state what elements there are in this circuit?

[fol. 209] Answer. When I saw this Lowenstein transmitter I did not follow out the circuits, but merely noticed the characteristic features of the set as described in my previous answer.

48. Question. At the time you examined this Lowenstein transmitter was the function of the wave-changing switch explained to you?

Answer. It was.

49. Question. And what was the function of this switch?

Answer. The function of this switch was to effect a quick change in the values of the inductance in the open radiating circuit and in the closed oscillating circuit of the transformer, thereby effecting quick changes in the wave lengths emitted by the transmitter.

50. Question. What type of detectors have been most generally used by the Navy, so far as you know, since 1910?

Answer. Various types of crystal detectors, such as iron pyrites, silicon and arsenic; the pericon detector, composed of chalcopyrites and zincite; the galena and carborundum detectors; plain audion, ultra audion, and ticker were also used as detectors.

51. Question. You stated that while in the Navy service you became familiar with the Federal Telegraph transmitting apparatus, and in this connection I call your attention to "The Proceedings of the Institute of Radio Engineers,"

volume 4, No. 5, October, 1916, and particularly to an article purporting to have been published by Capt. William H. Bullard, U. S. N., which describes and illustrates a Federal Telegraph transmitter installed at Arlington. Please examine this article and state whether or not you are familiar with the Federal Telegraph transmitter illustrated and described therein.

Answer. During the early part of the year 1915 I was stationed at the Arlington Radio Station under instructions and saw the Federal arc transmitter, described in this pamphlet, in operation at that station.

* * * * * * *

53. Question. At the time you saw this Federal transmitter did you examine it sufficiently to understand the circuit connections and also the essential elements of the apparatus?

Answer. While stationed at the Arlington Radio Station under instruction a complete and thorough knowledge of the Federal arc transmitter, including construction, circuit connections and operation, was required by the students in the regular course of their instruction. I studied the design and construction of the apparatus, connections, and operation of the transmitter, as required by the instructor.

54. Question. Will you now please describe this apparatus first without reference to Bullard's article and the drawings and photographs contained therein.

[fol. 210] Answer. The apparatus consisted of a motor generator, the generator of which supplied direct current at a pressure of 500 volts to the terminals of an arc through choke coils in both generator leads and an auxiliary resistance, which reduced the generator voltage on starting. The arc itself consisted of a chamber in which were located the arc electrodes. The positive electrode was made of copper and connected to the positive terminal of the generator. This electrode was water cooled; the negative electrode was of carbon and connected to the negative terminal of the generator through a series magnet. The electrodes were so arranged in the chamber that the pole pieces of this series magnet caused a magnetic flux to flow across the path of the arc. The arc chamber was of air-tight construction, and means were provided for introducing hydrocarbon vapor in this chamber. This was accomplished by dropping alcohol into the arc chamber from a small reservoir mounted

on top of the apparatus. The antenna was connected to the positive electrode through an antenna loading coil. The ground was connected to the negative terminal through a hot-wire ammeter. A battery of Leyden jars was shunted across the arc terminals for the purpose of increasing the stability of the arc. The choke coils in the generator lead were provided to localize the oscillations produced by the arc in the antenna circuit to keep them from reaching the generator. An ammeter and voltmeter were provided in the generator circuit to give indications of the value of voltage and current in this circuit. A switch was also provided in the generator circuit so that the continuity of the circuit from the generator to the arc could be controlled.

55. Question. Just how were the signals transmitted with this set?

Answer. The signals were transmitted by short circuiting a number of turns in the antenna-loading inductance. This was accomplished by means of a key. In sending signals by this method the circuit was not broken but radiated energy continually. By short-circuiting a number of turns in the antenna-loading inductance the wave lengths of the signal being transmitted was varied, the amount of variation depending upon the number of turns shortcircuited.

56. Question. Referring again to the article purporting to be by Capt. William H. Bullard, in the October (1916) proceedings of the Institute of Radio Engineers, do you know the Captain Bullard referred to? And if so, who is he?

Answer. I know Capt. W. H. G. Bullard, United States Navy. He was at the time I knew him superintendent of the naval radio service, with offices at the radio station, Radio, Va.

57. Question. I call your attention to Figure 13, on page 436 of the article State, if you know, what this figure shows.

*   *   *   *   *   *   *

Answer. This figure is a photograph of the Federal arc transmitter installed in the engine room of the radio station, Arlington.

58. Question. Please compare the circuit diagram of the Federal apparatus (fig. 14), shown on page 437 of this publication (P. Ex. No. 81), with the apparatus as you actually saw it installed and used.

[fol. 211] Answer. This figure is a wiring diagram of the circuit connections of the Federal arc transmitter as I saw it while at the Arlington station.

59. Question. Please point out on this diagram the several elements you have already stated form the parts of this apparatus.

Answer. This figure shows diagrammatically the following elements: Antenna loading coil *g*, sending key *b*, condenser *e*, arc electrodes and magnet *x*, starting resistance *w*, switch *s*, generator *a*, choke coils *y*, earth connection E, hot wire or radiation ammeter *p*, and voltmeter and ammeter in generator circuit A and V.

60. Question. Was the condenser or capacity shown at *e* in this drawing fixed or variable?

Answer. The condenser or capacity shown at *e* in the figure consisted of a battery of Leyden jars. The value of this capacity in this battery was adjusted for individual wave lengths.

61. Question. What does the arrow shown at 1 on this drawing indicate?

Answer. The arrow shown at 1 in this figure indicates a variable connection to the antenna-loading coil *g*.

62. Question. What use was made of this variable contact 1 and of the loading coil *g* in the operation of the set?

Answer. The position of the variable contact 1 on the loading coil *g* determined the value of the inductance in the coil *g*, on which depended the oscillation constants of the circuit *f*, *g*, copper, carbon, *p*, E, and the shunt circuit *e*. The wave length of the oscillations set up in this circuit was dependent on the oscillation constants of the said circuit.

Mr. Peters: I offer the article by Captain Bullard, containing the photographs and drawings to which the witness has referred, in evidence and request that the same be marked "Plaintiff's Exhibit No. 81, Bullard Institute of Radio Engineers article."

* * * * * * *

63. Question. I show you an instrument bearing a maker's name plate reading in part as follows: "DeForest Audion, Radio Tel. & Tel. Co., N. Y., U. S. A." To your knowledge, were instruments like this installed and used by the Navy subsequent to June, 1910?

Answer. While I was stationed at San Juan, P. R., in the year 1914, an instrument similar to the one on exhibit was supplied to that station, installed, and operated under my direction.

64. Question. Have you seen them in use at other naval stations?

Answer. I have seen them in use at other naval stations.

65. Question. State where and give the dates as near as you can.

Answer. I also saw one of these instruments in operation at the wireless station Brooklyn Navy Yard in the year 1914. I also saw several of these instruments in use during the year 1915 at the Arlington Radio Station.

66. Question. Please examine this instrument carefully and compare it with the one you installed and used in 1914.

Answer. After a careful examination of this instrument I find it to have connections similar to the connection of the instrument I installed and operated at San Juan.

[fol. 212] 67. Question. How do the several elements in the arrangement of elements compare with the one you installed?

Answer. They are identical.

68. Question. What name is this instrument known by in the naval service?

Answer. In the naval service this instrument was termed an audion control box.

69. Question. Have you made a drawing showing diagram-atically this instrument as used by you in the naval service in 1914? If so, will you produce the same?

Answer. This instrument could be used in several different ways, namely, as a plain nonoscillating audion, as an oscillating audion, or ultra audion, as it is called. I have prepared a sketch showing the circuit connections for use with this audion control box, utilizing it as a plain nonoscillating audion, and produce the same. I also have a copy of instructions issued by the Navy Department to me, giving descriptive matter and diagrams relating to the use of this audion control box as a ultra audion, and produce same.

69a. Question. When you installed and used one of these devices in 1914 in which of the several ways you have referred to did you install and use it?

Answer. I used it in both ways—that it, as a plain audion and as an ultra audion. When connected as a plain audion I used it for receiving damped or spark signals, and

while using it as an ultra audion, I copied or had copied undamped or arc signals.

70. Question. Please describe how you used this instrument as a plain audion for receiving spark signals, referring to the drawing you have produced if necessary.

Answer. The circuits *f*, A, *g'*, *j*[1] and earth E and *j*[2], *h'* (P. Ex. No. 83) were the ordinary primary and secondary circuits of the regular receiver in use at the station. The circuit containing the elements *j*[3], T, B[2], R, B[1] were the circuits of the audion control box. One lead from the condenser *h'* was connected through the condenser *j*[3] to the grid G of the audion T. The other lead from the condenser *h'* connected to negative terminal of the filament F of the audion T. The battery B' was connected to the filament F as indicated.

71. Question. Will you please identify on the instrument referred to the part designated T in the drawing?

Answer. The part designated T on my diagram represents the audion or bulb element of the audion control box. This element is composed of a plate, grid, and filament mounted in a glass bulb from which the air has been exhausted. Leads from the outside of the bulb connect to the various elements mentioned.

72. Question. There are two of these lamps or bulbs on the instrument and only one shown on the drawing. How do you explain this?

Answer. The drawing I have produced is a diagrammatic one and shows the scheme of connections. The audion-control box is provided with two bulbs and duplicate control, only one of which is in operation at a time.

73. Question. The audion bulbs on this instrument appear to have only single grids and single plates—do they correspond in this respect to the ones you used or saw used? [fol. 213] Answer. The audion bulbs are made in two styles—one style having but a single plate and single grid. The other style having a double plate and double grid. I have used both styles.

74. Question. Plaintiff's Exhibit No. 71, certified copy of contract by the Radio Telephone & Telegraph Co. with the United States, on page *a*-2, contains a proposal on the part of the company to supply "the audion detector, P. N. type." Do you recognize that type of detector as having been used in the Navy?

Answer. I recognize the instrument on the exhibit as a general type of apparatus supplied by the De Forest company. The makers' name plate on these instruments described them as P. N. type. In the naval service, however, this type of instrument was generally called the audion-control box.

Mr. Peters. I offer the instrument referred to by the witness in evidence, including the two audion bulbs forming a part of the instrument, and ask that it be marked "Plaintiff's Exhibit No. 82, De Forest P. N. audion used by Navy."

* * * * * * *

Mr. Peters. * * * Plaintiff does not contend that this particular instrument was ever in the naval service or used by the Navy.

* * * * * * *

75. Question. * * * I will ask you again to compare this instrument both as to construction and as to circuit connections with those used by you in the Navy.

Answer. The instrument I have examined is identical in design, construction, and connections with the one I used in the naval service.

Mr. Peters. The exhibit is again offered in evidence and it is requested that it be marked as above indicated.

I also offer in evidence the drawing last referred to by the witness and request that the same be marked "plaintiff's Exhibit No. 83, drawing, De Forest P. N. audion used by the Navy."

76. Question. I now call your attention to plaintiff's Exhibit No. 74, certified copy of contract between Radio Telephone & Telegraph Co. and the United States, which is dated June 27, 1914, and which calls for the delivery, among other items, of "Item 1, 30 single ultra audion detectors, complete, with 6-volt Hudson filament, and double bulb, without telephone receiver." While in the Navy, did you see any apparatus of this kind installed and in use; and if so, where and when?

Answer. As I stated in a previous answer, the so-called audion-control box could be connected with a receiver by

means of a circuit known as the ultra-audion circuit. Written instructions and diagrams of circuit connections were issued by the Navy Department, showing how the audion-control box could be connected with a receiver to produce this ultra-audion circuit.

[fol. 214] 77. Question. The instructions you have produced and referred to in one of your preceding answers are entitled "The ultra audion—its use with the various models of the 1-P-76 receivers in the U. S. Navy radio stations on board ship and on shore." State the time as near as you can when these instructions were issued to you.

Answer. These instructions were issued to me some time between November, 1914, and March, 1915.

78. Question. And when and where was it you installed and operated these ultra-audion instruments as described in these instructions?

Answer. I installed and operated and directed the operation of the apparatus described in this circular at the naval radio station, San Juan, Porto Rico, after having had received the instructions referred to in the preceding answer and prior to March, 1915.

79. Question. Have you seen these ultra-audion arrangements in use at other naval stations?

Answer. I saw this ultra-audion circuit in operation at the Arlington Radio Station during May, 1915.

80. Question. Please compare the ultra audion as you used it and saw it used in the naval service, with the description of the ultra audion and directions in the pamphlet referred to.

Answer. The ultra-audion circuit which I installed at San Juan was identical with the diagram on sheet 9 of the pamphlet under discussion. I installed this circuit at San Juan according to the instructions and diagrams contained in the pamphlet which had been officially issued to me.

81. Question. Is the pamphlet referred to an official publication or pamphlet of the Navy Department?

Answer. This pamphlet was issued by the Bureau of Steam Engineering and contained the official number RE-3A-101A.

Mr. Peters. I offer the pamphlet referred to in evidence and request that the same be marked "Plaintiff's Exhibit No. 84, official instructions for use of ultra audion."

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82. Question. The contract last referred to also calls for the delivery, under item 5, of 200 Hudson filaments, 6-volt double bulbs for use with item 1. What was called for by this item?

Answer. I do not understand the question in reference to "double bulbs."

83. Question. I call your attention to plaintiff's Exhibit No. 72, contract dated January 12, 1914, between Radio Telephone & Telegraph Co. and the United States, which provides for the delivery to the United States, among other items, of "10 audion amplifiers complete." While you were in the naval service, did you install and use any audion amplifiers? If so, where and when?

Answer. While I was stationed at the naval radio station, San Juan, P. R., a De Forest audion amplifier three stage was supplied to the station between November, 1914, and March, 1915.

84. Question. Did you examine the same sufficiently to understand its construction and circuit connections?

Answer. I did.

85. Question. Have you seen the devices in use at any other stations? And if so, name some of them.

[fol. 215] Answer. I saw the De Forest audion amplifier in use at the Arlington Radio Station in May, 1915, also at the Tuckerton Radio Station after that station had been taken over by the Government in April, 1917.

86. Question. Have you prepared a drawing showing the De Forest audion amplifier? And if so, will you please produce the same?

Answer. I have prepared a drawing (P. Ex. No. 85) showing the wiring diagram of the De Forest audion amplifier used by the Navy and produce the same.

* * * * * * *

87. Question. Please describe the De Forest audion amplifier as used by you and others in the Navy in 1914 and 1915, referring, if necessary, to the drawing you have prepared and produced.

* * * * * * *

Answer. The DeForest audion amplifier as used by myself while in the Navy was of the three-stage type; each stage consisted of an iron-ore transformer, 1, 2, 3, three-

element audion T, battery B^2, resistance ⋂ switch S, telephones R, and a filament lighting battery B′, which was common to all three stations. These elements were mounted in a wooden cabinet and the variable portions of the apparatus were operable on the outside. The terminals X Y were connected to the telephone binding posts or terminals of a receiver. The battery B′ was a separate piece of apparatus and connected to terminals on the amplifier. The amplifier element T was renewable. The circuit connections used are as shown in the diagram.

88. Question. At the time you were in the naval service did you receive any instructions as to the way the DeForest audion amplifier could be connected and used? By "connected" I mean connected to the antenna or receiver circuit?

Answer. I remember reading instructions published by the Navy Department and referring to the DeForest audion amplifier in which it was stated that the first stage of the amplifier could be used as an audion or ultra audion, the remaining two stages performing their usual function as amplifiers.

89. Question. Have you a copy of the instructions?

Answer. I have not.

90. Question. Did you ever use the amplifier or see others use the amplifier in this way while in the naval service?

Answer. I never found it necessary to use the amplifier in this manner, nor have I seen it used. The instructions I have referred to stated that it was possible to use the first stage of the amplifier after this fashion.

91. Question. When you used the amplifier how did you connect it to the wireless system?

Answer. The terminals X Y, drawing, DeForest audion amplifier, were connected to the telephone terminals of the receiver, the signals of which it was desired to amplify.

[fol. 216] 92. Question. Can you produce an illustration or photograph of the amplifier such as you used and saw used in the naval service?

Answer. A photograph of the DeForest audion amplifier similar to that used by me in the naval service is shown on page 192 of Bulletin A-14, apparently published by the Radio Telephone & Telegraph Co.

Mr. Peters. I offer in evidence the drawing produced by the witness and identified as showing the circuits of the

DeForest audion amplifier, and request that the same be marked "Plaintiff's Exhibit No. 85, drawing, audion amplifier used by the Navy Department."

I also offer in evidence the DeForest circular referred to by the witness with respect to page 192, containing the illustration of the amplifier, and request that the same be marked "Plaintiff's Exhibit No. 86, illustration, DeForest audion amplifier used by Navy."

93. Question. You have referred in your testimony to type IP-76 receiver. Do you know the maker of that receiver?

Answer. I referred in my testimony to a Wireless Specialty Apparatus Co.'s receiver also known as type IP-76.

Cross-examination.

By Mr. Workman:

* * * * * * *

94. Cross-question. In what capacity did you enter the Navy Department?

Answer. I enlisted in the United States Navy on January 6, 1904, as apprentice, third class.

95. Cross-question. Previous to entering the Navy Department, what electrical education or training had you had?

Answer. None.

96. Cross-question. At what time after entering the Navy Department did you begin working as electrician.

Answer. In May 1908, I was ordered to the Naval Electrical School at the Brooklyn Navy Yard, from which I graduated as electrician, second class.

97. Cross-question. That training in the Electrical Naval School had to do only with electrical power and lighting machinery, hadn't it?

Answer. It had to do with the practical application of electricity for use on board ships, also a theoretical general knowledge of electricity, and included in addition thereto a special course on radio telegraphy.

[fol. 217] 98. Cross-question. How long were you in the electrical school before you graduated?

Answer. I do not remember. A record of the length of time and my proficiency marks while attending this school could possibly be obtained from the Navy Department.

99. Cross-question. Was there not some fixed term after entering the school before graduation—wasn't it a three years, or a four years, course, or something like that, that was required for graduation.

Answer. There was a fixed period of instruction, but was less than a year.

100. Cross-question. Can't you give us some idea as to how long you were in this school—whether it was less than a year or a year or two or more?

Answer: It was about six months.

101. Cross-question. After leaving the school what position or duties were you assigned to?

Answer. I was assigned to the U. S. S. *Prairie*, as junior radio electrician.

102. Cross-question. Do you mean that you began radio work at once after leaving the school?

Answer. Upon my assignment to the *Prairie*, after leaving the school, I began at once the practice of radio telegraphy.

103. Cross-question. You weren't put at handling wireless apparatus, were you, at once after leaving the school in 1904?

Answer. I stated I did not begin my course of instruction at the school until May, 1908. When I was assigned to the *Prairie* after graduating from the school, I stood regular watch alternating with the electrician in charge and operated and kept in repair the wireless apparatus that was installed on the vessel.

104. Cross-question. Do you mean to give us to understand that with only six months' training, you not only learned the subject of electricity so as to be an electrician, but you also learned telegraphy and still further knew the subject of wireless telegraphy and its instruments and circuits?

Answer. During the period from the time I entered the service in 1904 until the time I was assigned to the electrical school for instruction, a period of approximately four years, I studied the subject during my spare time and received the assistance of several naval officers and electricians. It was necessary before being admitted to the electrical school to pass a preliminary examination to show that the applicant had some knowledge of the subject of electricity. My knowledge of electricity and of operating wireless apparatus is indicated by the fact that I graduated with the

rate of electrician, second class, instead of the ordinary graduation to electrician, third class. After being assigned to my duties on shipboard, I took a correspondence-school course in electrical engineering and graduated and received a diploma as an electrical engineer from this school. My knowledge of wireless telegraphy has also been augmented by the study of the various publications issued by the Navy Department and by the study of standard textbooks on the subject.

[fol. 218] 105. Cross-question. How much of your six months in the electrical school was devoted to the subject of wireless telegraphy?

Answer. Approximately one-third of the time.

106. Cross-question. You were a full-fledged wireless man when you were assigned to the *Prairie*, were you?

Answer. My rate was electrician, second class; my duties were junior radio electrician on board the *Prairie* and an electrician, first class, was the senior and I worked under his orders.

107. Cross-question. An ordinary electrician knows little or nothing about wireless apparatus and its operation, does he, unless he has made a study of the subject?

Answer. I am not prepared to answer a question of that nature except as it refers to myself.

108. Cross-question. Well, would you take an ordinary electrician and put him on wireless instruments without knowing whether or not he had studied the subject or had experience in it?

Answer. I do not understand the term "ordinary electrician." In the naval service electricians were rated in classes, their rate depending upon the extent of their knowledge and experience.

109. Cross-question. My question hadn't any reference to the Navy. I will ask you whether or not you would regard a man without any study or experience in wireless instruments and apparatus as able to handle, adjust, or operate such apparatus or understand its working?

*   *   *   *   *   *   *

Answer. A man without any knowledge whatsoever of the subject naturally could not be expected to perform the functions specified in the question.

110. Cross-question. Is the Lowenstein apparatus or transmitter referred to by you in your questions 4 to 8 the same one you again mentioned in questions 41, 42, etc.?

Answer. It was.

111. Cross-question. How do you fix the time as during the year 1914 that you saw a Lowenstein transmitter in the New York Navy Yard?

Answer. Because I was ordered from San Juan, Porto Rico, to the navy yard, Philadelphia, via the New York Navy Yard, for the purpose of examination for promotion. My orders required me to report to the New York Navy Yard, from whence I was later sent to the Philadelphia yard. It was during this visit to the New York yard that I saw the Lowenstein set in question.

112. Cross-question. You have no knowledge of how long that set had been there, I suppose?

Answer. Only from the fact that the instruments were new and had not been in operation for a great period of time.

113. Cross-question. And you don't know whether or not the Government has used other Lowenstein sets elsewhere prior to this time?

Answer. I have no knowledge of the installation or operation of any other Lowenstein transmitters.

114. Cross-question. This was the first one you ever saw?

Answer. This was the first Lowenstein transmitter I had ever seen.

[fol. 219] 115. Cross-question. What was there about it that you recognized as the Lowenstein set?

Answer. I had read descriptions of the Lowenstein apparatus and the characteristic features of same, and I recognized the set by these features. The operator in charge of the station at the New York Navy Yard explained the set in detail to me, also pointing out its characteristic features, such as spark gap, oscillation transformer, etc.

116. Cross-question. Well, doesn't every wireless set have a oscillation transformer and a spark gap—that is, of course, I mean those that don't use an arc or an audion or something like that in place of a spark gap?

Answer. Some form of spark gap and oscillation transformer is the essential part of spark or damped wave transmitters. There is a multiplicity of designs of this apparatus.

117. Cross-question. You have said that the Telefunken apparatus had a quenched spark gap and also an oscillation

transformer (at Q. 16). So there was no difference in this respect between the Lowenstein set you referred to and the Telefunken, was there?

Answer. The Telefunken set I referred to had a spark gap and oscillation transformer, but of an entirely different type than the one I saw on the Lowenstein transmitter.

118. Cross-question. And this difference readily appears at a glance, does it, so that you can instantly tell a Lowenstein set from a Telefunken set?

Answer. The difference between the spark gap and oscillation transformer of a Telefunken set and the same on the Lowenstein set was strikingly apparent. A person having seen the two could not possibly mistake one for the other.

119. Cross-question. Then this difference, as I understand you, is apparent on a mere glance of the apparatus without taking any of it apart or looking at the inside of the casings or anything of that kind. Is that correct?

Answer. The design and construction of the two types were apparent at a glance—that is, it was possible to recognize either one by the features of construction. However, they serve the same purpose in the closed oscillating circuit of the transmitter. The Lowenstein gap would operate in a Telefunken circuit and similarly the Telefunken gap would work in the Lowenstein circuit. It was only the design and construction of the two that differed.

120. Cross-question. As I understand it, any receiving apparatus will detect and receive signals from any kind of transmitting apparatus. Is that correct?

Answer. Any receiver can be made to receive and detect within its range any form of signal—that is, damped or undamped oscillations—provided proper auxiliary appliances are supplied; that is, to detect damp oscillations in a receiver some form of rectifying detector must be used, such as the various forms of crystal detector, Fleming valve, or what is called the plain audion; to detect undamped oscillations in a receiver, some form of beat producer or ticker must be used, such as the ultra audion, heterodyne, or ticker.

121. Cross-question. You referred to certain contracts in your direct examination, for example plaintiff's Exhibit 46, [fol. 220] Telefunken contract of September, 1911. You have no knowledge, I suppose, as to whether or not the apparatus specified in that contract was actually supplied to the Government, have you?

Answer. I have no knowledge of the various contracts specified in the direct examination. I confined my description of apparatus to that which I actually saw in the naval service, irrespective of under what contract the apparatus in question was purchased.

122. Cross-question. That is, you don't know whether this contractor, the Telefunken company, actually shipped to the Government the thing specified in that contract or not?

Answer. I have no knowledge of the delivery by the contractor to the Government of any apparatus whatsoever.

123. Cross-question. And if it did deliver it to the Government under this contract you have knowledge as to whether or not the apparatus it delivered was in accordance with the specifications of that contract?

Answer. The apparatus which I have described follows the specifications and diagrams shown in this exhibit. I have no knowledge as to whether the apparatus I described was the identical apparatus that the contractor delivered to the Government under this contract.

124. Cross-question. As to this sketch in the diagram you introduced of Telefunken apparatus, did you make that yourself?

Answer. The drawing I produced of the Telefunken apparatus was drawn by a draftsman according to instructions and pencil diagrams which I had approved.

125. Cross-question. Your drawing of the Telefunken set does not appear to be like the drawing accompanying the contract, plaintiff's Exhibit No. 46 of the Telefunken company, to the ordinary eye. Is it your testimony that your sketch agrees with this drawing in the contract?

Answer. The sketch which I have produced is a simplified, schematic drawing, such as is used in general practice to indicate the circuits of wireless telegraph apparatus. The drawing in the exhibit is a detailed diagram of connection. The two drawings are elementarily the same.

126. Cross-question. Did you observe that in a letter dated August 22, 1912, forming part of this exhibit contract of the Telefunken company, that that company states as follows:

"The sets covered by our bid are not in accordance with specification 16-T-5, etc., and we are unable to comply strictly with the other paragraph of the specification 16-T-5 without seriously impairing not only the usefulness but also the efficiency of the set as a whole."

And various other parts of this letter indicating differences between what was specified and what was offered to be furnished?

*   *   *   *   *   *   *

Answer. I have read over the exhibit, including the certified copy of the letter dated August 22, 1912, relating to differences between what was specified and what was offered to be furnished.

127. Cross-question. When was it you made the pencil instruction for the draftsman of this diagrammatic sketch of the Telefunken apparatus?

[fol. 221] Answer. The draftsman was instructed to prepare the diagrammatic sketch of the Telefunken apparatus from pencil notes and verbal instructions on Tuesday, June 26, 1917, and on the following day several necessary changes were made.

128. Cross-question. Did you obtain the necessary data to give to the draftsman for this drawing from your memory?

Answer. The data given to the draftsman for the preparation of these drawings was given from my memory.

129. Cross-question. You took none of this data from instruction pamphlets or other diagrams or from some of the drawings that were furnished you, did you?

Answer. I obtained no data from reference books or descriptive pamphlets in the preparation of this diagram. As I was charged with the responsibility of the installation of a Telefunken transmitter while at San Juan, a knowledge of the circuit connections of this apparatus is quite firmly impressed in my mind.

130. Cross-question. Then as I understand you made your transmitting apparatus on this sketch from your memory unaided of the one you installed at San Juan. Is that correct?

Answer. The instructions and data I furnished the draftsman for the preparation of this diagram—that is, as it relates to the transmitting portion of the same—was entirely a product of my memory.

131. Cross-question. What was the occasion for your leaving the naval service?

Answer. I left the naval service because of expiration of enlistment and because of physical disability.

132. Cross-question. In describing these various wireless installations and apparatus you have used, of course, many technical terms which the ordinary layman and possibly the court will not understand. Will you please therefore state what is meant by "wave lengths"? For example, you say in describing this Telefunken apparatus that H is a "shortening condenser for use in transmitting short wave lengths only." (Q. 16.)

Answer. By "wave length" is meant the length from crest to crest of an electromagnetic wave radiated from the antenna of the transmitter. The frequency of an electromagnetic wave in cycles per second is analogous to wave lengths. To produce a given wave length with a transmitter the closed oscillating circuit has to be adjusted, that is the value of the inductance and capacity in that circuit must be so chosen that the natural period of that circuit will be the same as the frequency (cycles per second) of the electromagnetic wave that it is desired to produce. The antenna or open radiating circuit of the transmitter has also got to be adjusted to this frequency. It is sometimes desired to transmit a wave length smaller than the natural or fundamental wave length of the antenna. In order to accomplish this, the natural wave length or period of the antenna has to be reduced. The condenser H in the diagram referred to accomplishes this purpose, that is, reducing the fundamental or natural period of the antenna so that it is possible to transmit wave lengths of a shorter length than the natural wave lengths of the antenna.

133. Cross-question. A wave length of a given dimension is a wave of a corresponding definite frequency. Is that right?

[fol. 222] Answer. A wave of a given length corresponds to a certain definite frequency. Knowing the frequency, it is very easy to calculate the wave length—in fact the wave length is almost apparent from inspection. Knowing the velocity of the wave, and the number of waves per second, dividing the former by the latter, will give the wave length.

134. Cross-question. Instead of speaking of wave lengths, you could just as well express the same thing as accurately by giving the frequency, couldn't you?

Answer. Frequency and the wave length mean essentially the same thing. In general practice, both terms are used as a designation of this phenomena.

135. Cross-question. You speak of the radiating circuit or the open radiating circuit in this Telefunken apparatus, and I understand that to be the circuit which includes antenna *f*, conductor A, coil *g*, switch S, coil *d'*, and earth E. Is "radiating" "circuit the common name or term for this circuit as used by wireless men?

Answer. This circuit is designated by either one of the following terms: "Open circuit," "radiating circuit," and "open radiating circuit," to distinguish it from the closed or closed oscillating circuit of the transmitter. This circuit is "open" in the sense that it is not a continuous metallic circuit and "radiating" in the sense that a portion of this circuit is used in the radiation of electromagnetic waves. All these terms are used in general practice as a designation for this particular circuit.

136. Cross-question. As a matter of fact this circuit that we have just referred to is not an open circuit at all and it doesn't radiate. Isn't that correct?

Answer. On the contrary, it is both an open circuit and also a radiating circuit.

137. Cross-question. Well, whatever takes place in this circuit has to reach the receiving station, doesn't it? Otherwise your apparatus is useless.

Answer. A portion of the electromagnetic field set up around this circuit due to the current impulses induced in this circuit by the closed oscillating circuit of the transmitter is radiated off into surrounding space. These radiated electromagnetic waves are the ones that are picked up by the receiving station.

138. Cross-question. But your sketch of the Telefunken apparatus shows both these circuits at the transmitting and receiving stations, respectively connected to earth, doesn't it?

Answer. The connection to earth E shown on my diagram is an essential part of the open circuit of both the transmitter and the receiver.

139. Cross-question. Isn't it necessary to connect both the transmitting and the receiving antennae to the common conductor, earth to transmit signals from one to the other?

Answer. It is not necessary to connect the earth connection E to a common conductor. Take the case of airplane, where the earth connection is made to the metal framework of the airplane, while the antenna consists only of a hang-

ing wire. The receiving station receiving signals transmitted by this airplane has no common connection with the transmitting apparatus the signals of which it is receiving.

[fol. 223] * * * * * * *

140. Cross-question. Then it isn't correct what is stated in this Instruction Manual of Wireless Telegraphy for the Use of Naval Electricians for 1915, which, I understand, was one of your instruction books, where it states on page 62, "The expanding rings touch the earth and are guided by it as by any other conductor." Would you say that?

Answer. According to this theory of the propagation of electromagnetic waves, as written in the instruction book referred to, it is probably true that the waves act in the manner described therein. These waves, however, are waves in the so-called medium ether and not currents of electricity, as I understand it.

141. Cross-question. Then your closed oscillating circuit, so called, of this Telefunken apparatus, *c*, G, 2', *d*, 2, isn't closed at all, is it, any more than the antenna circuit?

Answer. When current is flowing in this so-called oscillating circuit it is, in fact, a closed circuit. When current is not flowing in this circuit the circuit is open at the point G.

142. Cross-question. But this circuit is open at what you have called a capacity *c*, isn't it? No electrical current flows across *c*, does it?

Answer. It is a closed circuit for alternating or oscillating current, but not a close circuit for direct current. However, as only alternating or oscillating current is ever used or produced in this circuit, it remains a closed circuit, as far as practice is concerned.

143. Cross-question. And it isn't oscillating or alternating current that occurs in the antenna circuit. Is that what you mean?

Answer. Alternating or oscillating current also occurs in the antenna circuit.

144. Cross-question. Capacity *c* is only another name for condenser *c*, isn't it?

Answer. Capacity at the point *c* is obtained by the use of condensers at this point—in other words, condensers have concentrated capacity.

145. Cross-question. There are different terms used for what look the same things on the drawing. I merely want to clear this up for the benefit of the court. In your answer

to Q. 16, you refer to "condenser H;" also "capacity *e*," and in the receiving circuit "condenser *h*, condenser j^3." These are all condensers, are they not?

Answer. They are all various forms of condensers.

146. Cross-question. And a condenser is a number of plates of metallic or conducting material separated one from the other by some intervening nonconductive or insulating material. Is that right?

Answer. They are the elements which form a condenser.

147. Cross-question. In the Telefunken apparatus you have referred to, what did the condenser or capacity *e* consist of?

Answer. The condenser or capacity *e* referred to consisted of a bank of Leyden jars.

[fol. 224] 148. Cross-question. This Telefunken set to which you have referred and made a sketch of does not seem to agree with an illustration of the Telefunken apparatus which I find on page 107, Figure 46, of the Manual of Wireless Telegraphy for Naval Electricians, 1915, does it?

Answer. The arrangement of the elements of the Telefunken apparatus, Figure 46 in the manual referred to, is slightly different than shown in my sketch; however, the manual does not state that Figure 46 is the type of Telefunken wiring that was used at the San Juan station, while I have stated that I drew my sketch of the Telefunken apparatus from my memory and according to the manner in which I installed this set while at San Juan. I did not obtain any data from the manual referred to in connecting up the transmitter I installed.

149. Cross-question. You have referred to what you called a quenched spark gap G in this Telefunken apparatus. What does this mean—"quenched spark gap"?

Answer. By "quenched spark gap" is meant a type of gap that effects the quenching or stoppage of the flow of current in the closed oscillation circuit after the amplitude of the discharge from the condenser *e* falls below a certain value.

150. Cross-question. What is the effect of this quenched spark gap on the so-called waves that are sent out from the transmitting station as distinguished from those that are sent out when an ordinary or unquenched spark gap is used.

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Answer. The quenched spark gap quenches the discharge of the condenser in the closed oscillating circuit after the discharge of this condenser has reached a certain point. After the quenching action has occurred, the transformer again builds up the charge on the condenser until that charge is of a value sufficient to again break down the resistance of the gap. This action is repeated indefinitely as long as the sending key is closed. In the case of the open or nonquenching type of gap no quenching action occurs; that is, in the sense of quenching the discharge of the condenser after it has fallen to a certain value—in other words, the condenser discharge flows through the closed oscillating circuit for a greater period of time than is the case with the quenched gap. The wave trains in a circuit containing an open, or nonquenching, gap have a greater number of oscillations per train. In the quenched form of gap, greater radiating surface is provided for cooling the elements. This has the effect of maintaining a practically constant resistance in the gap. In the quenched gap the spark occurs in practically an air-tight chamber, in which conducting vapors are at a minimum. This feature also serves to help [fol. 225] maintain a constant gap resistance. In the open, or nonquenching, gap little provision is made for cooling the electrodes. The spark also occurs in open air and it is claimed that the spark ionizes the air and vapors in the vicinity of the spark; these vapors, being conductive, reduce the resistance of the gap. The decrement of the oscillations is effected by this variation in gap resistance. From the foregoing, it is readily seen what effect on the radiated waves of a transmitter the two different types of gap have.

151. Cross-question. As I understand your testimony, the Telefunken apparatus which you installed at San Juan was only a transmitting apparatus. Is that correct?

Answer. Yes, sir.

152. Cross-question. What did they use for receiving at that station at that time?

Answer. The following equipment was supplied to the San Juan station to which I was attached: Three I. P. 76 Wireless Specialty Apparatus Co.'s receivers, one audion control box with spare bulbs, one DeForest audion amplifier with spare bulbs, two Edison nickel-iron storage batteries for use in connection with the audion control box and De-

Forest amplifier; a number of spare crystal detectors was also a part of the equipment.

153. Cross-question. Were all these various types of instruments installed and used at this time for receiving at San Juan?

Answer. These various types of instruments were all used at various times for receiving signals.

154. Cross-question. And how about the apparatus you saw on the *Louisiana*—was that Telefunken apparatus both transmitting and receiving?

Answer. I do not remember if the transmitting apparatus on the *Louisiana* was of the Telefunken type, but am inclined to believe that it was. The receiving apparatus included the Telefunken receiver I referred to.

155. Cross-question. What was the occasion of your visit to the *Louisiana* when you saw the Telefunken apparatus you have referred to? Was this merely a casual visit to the ship?

Answer. I visited the *Louisiana* on the invitation of a friend who was in charge of the wireless on that vessel to look over the new installation of wireless apparatus that was being installed at the time.

156. Cross-question. How long were you on the ship on this occasion?

Answer. Probably several hours.

157. Cross-question. Is all this apparatus represented in your sketch of the Telefunken apparatus—for example, located in one room or on one table or panel?

Answer. The receiving apparatus I saw on the occasion of my visit to the *Louisiana* was mounted on a desk or shelf.

158. Cross-question. You did not take any of the apparatus apart on the *Louisiana*, I suppose, nor remove any covers or casings?

Answer. I did not take any of the apparatus apart or remove any part of same, as the entire Telefunken receiver was available for close inspection without the necessity of resorting to such procedure.

159. Cross-question. Well, how can you tell what the wiring of the circuits is by merely looking at an apparatus on a shelf?

[fol. 226] Answer. The wiring on a Telefunken receiver is apparent from inspection. The shelf I referred to was a long table or shelf built across the wireless room and was used as an operating desk. The receivers, sending key,

and various other parts of the apparatus were also mounted on the shelf.

160. Cross-question. And are the coils *d d'* also mounted in full view on this shelf?

Answer. These coils were mounted near the top of the receiver and were not inclosed in any way—in fact, it was necessary at times to substitute coils of various inductance, so that the coils had to be readily available in order that the operator might effect the change. The foregoing refers to the receiving apparatus. The coils I refer to as *d d'* should have been referred to as *j* and j^2. I do not remember, while on my visit to the *Louisiana*, of observing the coils *d d'*, as these coils are a part of the transmitting apparatus.

161. Cross-question. You saw both Telefunken transmitting and receiving apparatus on the *Louisiana*, as I understand it. Is that right?

Answer. I saw the Telefunken receiving apparatus on the *Louisiana*, but paid no particular attention to the type of transmitting apparatus.

162. Cross-question. As a matter of fact the transmitting apparatus on the *Louisiana* on this occasion might have been some other type than Telefunken, so far as you remember. Is that true?

Answer. Possibly.

163. Cross-question. I understand that on the *Louisiana* you saw two types of Telefunken receiving apparatus E4 and E5. Were these both installed and in use or for use, or was one of them not connected up?

Answer. The two types of receivers mentioned were in the wireless room, but, as the ship was in the navy yard undergoing repairs, the wireless apparatus was not being used. As this particular wireless station was undergoing change, it is possible that these receivers were not actually connected with the antenna. I merely state that I saw these receivers on board this vessel.

164. Cross-question. In your Q. 18 answer, these adjustments that you spoke of, such as varying the wave lengths—was that what you call tuning?

Answer. By tuning a transmitter is meant the adjustment of that transmitter to a given wave length. Changing the wave length does not necessarily require tuning at every change, as it is possible to tune a transmitter to any predetermined number of wave length and at some later

time operate the transmitter at any one of these wave lengths.

165. Cross-question. You choose the frequency of oscillation or wave length you desire to use, and to do so you change this variable contact 2; is that what is meant by the first part of your answer to Q. 18?

Answer. By changing the position of the variable contact 2 on the coil *d*, you choose an amount of inductance in this coil *d*, and thus set the closed oscillating circuit *d*, *e*, G, 2ª, to a definite wave length. In order that the transmitter [fol. 227] as a whole operate on this wave length it has been necessary to tune the open oscillating circuit, which is coupled to the closed oscillating circuit.

166. Cross-question. Why don't you shift the contact 2ª for doing this?

Answer. It is also possible to shift the contact 2ª, the main requirement being that the amount of inductance in the coil *d* between the points 2 and 2ª be sufficient in conjunction with the capacity *e* to give the wave length required in this closed oscillating circuit.

167. Cross-question. You then say in your answer to Q. 18, "the open oscillating circuit is then tuned with the closed oscillating circuit by varying the amount of inductance in the coils *d'* and *g*." Now if this coil *d d'* is in fact only one coil, as I understand, how can you then tune the open oscillating circuit by varying the amount of inductance in the coil *d'* when you have already got that set to your wave length when you tune the closed oscillating circuit?

Answer. The amount of inductance in the coil *d'*, that is, the inductance in the open oscillating circuit, is shown in the diagram as between the point figure 1ª and the point 2ª, while the amount of inductance in the coil *d* is between the points 2 and 2ª. It being a single coil, it follows that the inductance between the points 2 and 2ª is common to both the closed oscillating circuit and to the open radiating circuit. This form of connection is generally known as the direct coupling.

168. Cross-question. Well, if you shift the contact 1ª on the coil to tune the open circuit with the closed circuit you also change your inductance in that closed circuit from what you had first set it?

Answer. Varying the contact 1ª and consequently the amount of inductance in the open oscillating circuit has no

effect whatever on the positions of the contact 2 and 2^a, which contacts alone determine the amount of inductance in the closed oscillating circuit. The amount of inductance in the open radiating circuit is contained on the coil *d'* between the points 2^a and 1^a.

169. Cross-question. Do you mean to say that varying 1^a changes the inductance in the coil *d'* when it is considered as being in the open circuit but doesn't change its inductance if you consider it as being in the closed circuit, it being the same coil all the time?

Answer. Varying the inductance of the coil *d'* varies the inductance between the point 1^a and 2^a. Varying the inductance in the loaded oscillating circuit varies the inductance between the points 2 and 2^a. These are two separate and distinct circuits, and while they have currents in common the inductance or change of inductance in one does not affect the amount of inductance in the other.

170. Cross-question. You don't mean to say, do you, that changing the contact point 1^a on the coil *d'* doesn't effect the action of that coil as a whole or all parts that are included between the contact point 1^a and the contact point 2^a?

Answer. The amount of inductance in the coil *d'* between the points 1^a and 2^a determine the value of the inductance of that portion of the coil in the open circuit. The amount of inductance on the coil *d* included between the points 2 and 2^a determine the value of the inductance of that portion of the coil in the closed circuit. The portion of the coil in- [fol. 228] cluded between the points 2 and 2^a is that portion of the coil which is common to both the closed circuit and the open circuit. The value of the inductance in the closed circuit is not changed by varying the point 1^a, nor is the value of the inductance in the open circuit changed by varying the contact 2.

171. Cross-question. But doesn't the inductance as determined by the contact 1^a react upon the inductance as determined by the contact 2? Don't these two circuits react one upon the other?

Answer. These two circuits react one upon the other, as is the case between any coupled circuits. The value or amount or number of turns of inductance in common to the two circuits determines the degree of coupling between those circuits.

172. Cross-question. It wouldn't be possible, would it, to send any intelligible wireless signals from any wireless

apparatus if you could not adjust the frequency or period of the antenna circuit to what you call the closed oscillating circuit? In other words, if you could not tune these circuits one to the other?

Answer. It might be possible to obtain an intelligible wireless signal under the conditions mentioned, but I never made any experiments of that nature.

173. Cross-question. Well, if the periods of oscillation in the two circuits were different, wouldn't one interfere with the other; counteract the other? And wouldn't you get a confused effect?

Answer. I have never carried on experiments to demonstrate the possibility or probability of the operation in the circuits described.

174. Cross-question. In this same answer you say that in receiving a signal on the Telefunken receivers it was necessary to tune the antenna to the wave length of the signal it was desired to receive. Do you mean to state that this is a peculiarity of the Telefunken receiver, and that it doesn't apply to all wireless receivers?

Answer. The receivers which I have seen and operated all embrace some form of tuning of the primary circuit.

175. Cross-question. You have mentioned in your direct testimony somewhere about various forms of detectors—some of which you called rectifying detectors, and others I believe you referred to as nonrectifying. Was the detector T in this Telefunken receiver a rectifying or a nonrectifying detector?

Answer. It was a rectifying detector of the single crystal type.

176. Cross-question. What does this mean, rectifying or nonrectifying detector?

Answer. I don't believe I referred to any type of detectors as being nonrectifying. A rectifying detector is one which will permit the passage of a current in a unidirectional way.

177. Cross-question. Referring to the National Electric Supply Co.'s apparatus, was this set set up and operated by you both as to the receiving and transmitting apparatus?

Answer. It was.

178. Cross-question. And who made this drawing of this National Electric Supply Co. that you put in evidence—you yourself or some one that you directed?

Answer. This drawing was prepared by a draftsman under my direction and upon data supplied by myself.

179. Cross-question. Did you give him any rough sketch to work from?

[fol. 229] Answer. I gave him a pencil sketch or diagram which had been approved by me.

180. Cross-question. Was such data or sketch as you gave him made from your memory of this apparatus which you saw on the *Georgia?*

Answer. The data for the preparation of this sketch was supplied to the draftsman from my memory of the connections of the set that I operated on the *Georgia.*

181. Cross-question. And you are able to keep in your memory the various devices, circuit connections, and apparatus of a number of different types for a number of years, are you?

Answer. Not the complete wiring diagram, but elementary sketches of connections.

182. Cross-question. Who was associated with you on the *Georgia* in this work with the National Electric Supply Co.'s apparatus?

Answer. I was the chief electrician in charge of the radio installation on board the *Georgia*, and I worked under the orders of the radio officer, who was an ensign in the Navy; several electricians of lower rating were under my orders.

183. Cross-question. Do you remember the name of this officer that you have referred to as ensign?

Answer. The radio officer was changed every six months, and while on the *Georgia* I was under the orders of several of these at various times. I do not remember their names.

184. Cross-question. Can you give me the name of anyone who was either your superior or under you in this work of testing the field set of the National Electric Supply Co. we are referring to?

Answer. I can not recall their names at the present time, but if I saw their names in print would recognize them. The Navy Department possibly has a record of the men referred to.

185. Cross-question. You spoke of this National Electric Co.'s set as having a crystal detector and a fine-wire contact. Was the crystal one member of the contact and the fine wire the other member?

Answer. The fine wire made contact to the surface of the crystal.

186. Cross-question. Just what was the nature of this contract? Was fine wire coiled about the crystal, or, briefly, just how was it?

Answer. The end of the fine wire made contact to the surface of the crystal—the area of contact being extremely small.

187. Cross-question. This was also a rectifying detector, wasn't it?

Answer. As I understand it, it was.

188. Cross-question. What enabled you to remember the date you gave for having seen this National Electric Supply Co.'s apparatus? Is that also a matter of memory?

Answer. I remember the date of having seen this set by reason of it having been received on board the ship just prior to the ship's being ordered to Vera Cruz, Mexico, to protect American interests during the revolution which was in progress in Mexico at that time, also due to the fact that this set was sent to the *Georgia* a short time after I myself had been sent there.

189. Cross-question. Referring to the Lowenstein apparatus in plaintiff's Exhibit No. 57 the contract, you have no means of knowing whether any apparatus was supplied under that contract or not, have you?

[fol. 230] Answer. I have no knowledge of the delivery of apparatus under any contract.

190. Cross-question. The date of your visit to the New York Navy Yard in the latter part of 1914—you gave that as a matter of memory, did you?

Answer. I was ordered North for examination for promotion, as I stated in one of my previous answers, and I have a copy of my orders in my personal files, which gave the date I mentioned.

191. Cross-question. How long did you spend examining this apparatus at the New York Navy Yard on that occasion?

Answer. Possibly several hours.

192. Cross-question. Why do you call the oscillation transformer B of the sketch in the Lowenstein contract a combination inductive and conductive transformer?

Answer. Because of its peculiar form of connection which I had never seen before used on any other type of transmitter.

193. Cross-question. Where in this drawing do you see the secondary transformer?

Answer. The secondary of this oscillation transformer is the portion of the circuit shown in the diagram A, loading inductance, quick change control B, B, A, hot wire ammeter earth connection.

194. Cross-question. Then you have also got the loading inductance, as both the loading inductance and the secondary of the oscillation transformer?

Answer. The diagram shows the loading inductance, primary inductance, and transmitter coupling adjuster as being in the same field.

195. Cross-question. And the way it is on this sketch is just the way it was on the apparatus you saw. Is that right?

Answer. As I remember it, it is.

196. Cross-question. Then according to this, the loading inductance is in the circuit of the so-called closed oscillating circuit, is it?

Answer. It is not.

197. Cross-question. Well, in this Lowenstein apparatus as shown on the sketch, what is called the loading inductance is also at the same time part of the oscillation transformer. Isn't that correct?

Answer. It is partially correct—strictly speaking only the coils marked primary inductance and transmitting coupler adjuster form what is generally known as an oscillation transformer—however, the coil marked loading inductance is also in the field of the other two coils.

198. Cross-question. There was one form of detector referred to in your Q. 50 called the tickler. What sort of a detector is this?

Answer. The form of detector known as the ticker was composed of a rotating metal disk upon which a fine wire contact was made.

199. Cross-question. Referring to the audion transmitter, produced in evidence, in the DeForest audion, what is the purpose of the part you have called a grid?

Answer. The function of the grid is to receive the charge of the grid condenser.

200. Cross-question. The audion is used both for the spark propagated waves as well as for what you have called the undamped or continuous oscillation. Is that correct?

[fol. 231] Answer. The plain audion can only be used in connection with damped oscillations, or spark signals.

201. Cross-question. Just what do you mean by "damped" and "undamped" oscillations or waves?

Answer. By "damped oscillation," I mean a series of wave trains, each wave train being composed of an oscillating wave each succeeding oscillation being damped or reduced a certain amount. By "continuous or undamped oscillation," I mean oscillations each succeeding wave of which is of equal amplitude.

202. Cross-question. To put it another way, would it be correct according to your ideas to say that a damped oscillation was one that gradually died out and an undamped oscillation is one that continued and doesn't substantially die out?

Answer. Damped oscillations are oscillations, each succeeding oscillation being of smaller amplitude, until the series of oscillations gradually cease altogether. A number of these surges, so to speak, form what is called a wave train. Undamped oscillations are oscillations that are continuous and have no damping.

203. Cross-question. Can you explain why or how it is, if I understand it correctly, that the same instrument or audion can be used to receive sparked or damped signals or oscillations and as an ultra audion can only be used for receiving continuous or undamped waves?

* * * * * * *

Answer. The plain audion can be used only for receiving damped or spark signals, while the ultra audion can be used for receiving both damped and undamped signals. An audion bulb can be so connected in a circuit that it will act either as a plain audion or as an ultra audion. The audion is an ultra audion only by virtue of the fact of the proper connections.

204. Cross-question. Have you testified in other patent suits relating to wireless telegraphy?

Answer. I have not.

205. Cross-question. Now, these various types of apparatus, for example, the Telefunken, you have referred to, one feature of the apparatus is a loading coil, and in the Lowenstein apparatus we found that this was partly in the transformer between the antenna and the oscillating circuit. How did you recognize this as a loading coil in these apparatuses.

Answer. An antenna loading coil is a coil having inductance that is used to increase the wave length or natural period of the antenna.

206. Cross-question. Would you call any coil you found in the antenna circuit a loading coil?

Answer. Any coil performing the function of increasing the natural period of the antenna and not used for the purpose of coupling to another circuit is in general called a loading coil.

207. Cross-question. Then you have to identify parts of the apparatus not so much by their appearance as by what they may be used for or their function?

[fol. 232] Answer. In naming a piece of apparatus, its function is generally taken into consideration. In the case of the antenna loading coil its function is to load or increase the natural period of the antenna.

208. Cross-question. And if you found an audion in a piece of wireless apparatus, you wouldn't necessarily know from its mere presence there whether it was an audion or an ultra audion, would you?

Answer. Not without an examination of the circuits.

Redirect examination.

By Mr. Cosgrove:

209. Redirect question. Was the Telefunken you installed at San Juan Navy Station a new set?

Answer. It was a new set; that is, the apparatus had never been used before except possibly for test purposes.

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210. Redirect question. How were you able to determine that this set had not been used before?

* * * * * * *

Answer. By the condition of the various parts of the apparatus.

211. Redirect question. Was the portable sets of the National Electric Supply Co. delivered aboard the *Georgia* new sets?

* * * * * * *

Answer. The portable set received on board the *Georgia* while I was stationed on that vessel was apparently a new one, and as far as I know had never been used before.

212. Redirect question. Referring to the wave-changing switch in the Lowenstein apparatus, referred to by you, why did this switch change both circuits; that is, the open-radiating and the closed-oscillating circuits?

Answer. So that a change from one wave length to another could be effected by means of one operation.

213. Redirect question. Did this change keep the circuits in tune?

Answer. The amount of inductance involved in the change from one point to another was fixed when the set was originally tuned to the predetermined wave length. When the wave-length switch was changed from one point to another, it affected a change in the value of inductance in both circuits, but the two circuits were in tune with each other.

214. Redirect question. You have referred on your cross-examination to audion bulbs having single plate and grid and others having a double plate and grid. While in the Navy, did you use both styles for detecting spark signals?

Answer. While in the Navy I used both styles for detecting both spark and arc signals.

Deposition of Ralph Herbert Langley, for claimant, taken at New York, N. Y., on the 30th day of June, A. D. 1917, and subsequent dates.

Claimant's counsel, James J. Cosgrove and John W. Peters; defendant's counsel, Henry C. Workman.

Ralph Herbert Langley deposed and said that his name is Ralph Herbert Langley; that his occupation is that of electrical engineer, with the Marconi Wireless Telegraph [fol. 233] Co.; that he is 29 years of age; that his place of residence is Roselle Park, N. J.; that he has no interest, direct or indirect, in the claim in controversy; and that he is not related to the plaintiff.

And thereupon the said Ralph Herbert Langley was examined by the counsel for the plaintiff, and in answer to interrogatories testified as follows:

Direct examination.

By Mr. Peters:

1. Question. What education, experience, and training have you had, if any, which qualifies you to testify regard-

ing the construction and operation of wireless telegraph apparatus?

Answer. I took a degree as electrical engineer at Columbia University in 1913, having completed a special course under Doctor Pupin on radiotelegraphy. I was engaged in the laboratory of Doctor De Forest in the same year; later by the National Electric Signaling Co., then by the Wireless Improvement Co. and by the Wireless Specialty Apparatus Co., and then finally by the Marconi Wireless Telegraph Co. of America. While I was with the Wireless Improvement Co. I was in charge of the design and construction of wireless telegraph transmitting apparatus. During the last six months that I was with the company —was chief engineer.

2. Question. It appears from plaintiff's Exhibit No. 60, contract by Wireless Specialty Apparatus Co. with the United States, dated September 21, 1912, that the Wireless Specialty Apparatus Co. contracted to deliver two 5-kw. 500-cycle motor-generator quenched-gap radiotelegraph sets to the Navy Department. Have you any knowledge or information regarding the manufacture and sale of sets of this kind by this company to the United States?

Answer: The two sets in question were built in Boston and shipped directly to the navy yard at New York. I saw these two sets at the navy yard and assisted in the acceptance tests, which were made there.

3. Question. When was it you assisted in the acceptance tests at the navy yard?

Answer. In the summer of 1913.

4. Question. What opportunity have you had to familiarize yourself with the receiving sets made and sold by the Wireless Specialty Apparatus Co. since the year 1910?

Answer. I have seen these receiving sets many times and have had used the same in experimental work. While I was with the Wireless Improvement Co., Col. John Firth, who was owner of the Wireless Improvement Co., was at the same time second vice president of the Wireless Specialty Apparatus Co. and was their New York agent. The receiving sets in question were always to be seen in his offices and that is where I became familiar with their construction.

5. Question. The contract last referred to also calls for the delivery, among other items, of the following receiving apparatus:

"(*a*) One highly selective receiver of special design for receiving wave lengths up to 10,000 meters, to be furnished with a variable condenser in primary circuit with loads which can be operated by switches to put this condenser in series or in parallel with inductance or to cut it out.

[fol. 234] "(*b*) One highly selective receiver with variable condenser, for primary circuit as required for (*a*), for receiving waves from 300 to 3,000 meters for ship communication.

"(*c*) One simplified receiver, range 300 to 3,000 meters, to consist of variable primary inductance, variable secondary, with means for varying the mutual inductance between the two circuits, and variable series condenser."

Are you familiar with any of the Wircless Specialty Apparatus receivers referred to above?

Answer. No; I am not familiar with the receiving apparatus mentioned in this contract. * * *

* * * * * * *

6. Question. Why do you say it was probably shipped to the Washington Navy Yard?

Answer. For some time past most receiver work has been done in Washington, and since I have no knowledge that these receivers passed through the New York offices, I assume they were shipped directly to Washington.

7. Question. Understanding that you did not see these particular receivers, I will ask if you, at the time this contract was made, September, 1912, were familiar with the various types of I-P-76 receivers manufactured by the Wireless Specialty Apparatus Co.?

Answer. At the time mentioned I was not familiar with these receivers, but the delivery on the contract in question was not made until over a year later and at the time I was familiar with these receivers.

8. Question. Plaintiff's Exhibit No. 62 calls for the delivery by the Wireless Specialty Apparatus Co. to the Navy of "8 I-P-76, series of 1912, receiving sets." Are you familiar with that particular type of receiver?

Answer. Yes.

9. Question. Plaintiff's Exhibit No. 63, among other apparatus, calls for the delivery by the Wireless Specialty Apparatus Co. to the Navy "10 radio receiving sets complete, type I-P-76, 1914." Are you familiar with that type of apparatus?

Answer. Yes, sir.

10. Question. What information, if any, have you regarding the delivery of any of these Wireless Specialty receivers to the United States Government subsequent to the year 1910?

Answer. I have no definite information that any of these receiving sets were actually delivered to the Navy Department, but Colonel Firth on many occasions informed me of the award to the Wireless Specialty Co. of contracts for these receiving sets, discussed with me the prices which the Wireless Specialty Co. were getting and on many occasions I saw a journal which he kept at the New York office in which these sales to the Government were recorded.

* * * * * * *

11. Question. When you saw the Wireless Specialty Apparatus Co. transmitters at the Brooklyn Navy Yard were they assembled for operation?

Answer. They were assembled for operation and were repeatedly actually in operation. They were at that time con- [fol. 235] nected to an artificial antenna in order that their testing might not interfere with other radio work at the navy yard, but were obviously intended to be used with a real antenna.

* * * * * * *

12. Question. Have you prepared and if so will you produce a drawing showing the Wireless Specialty Apparatus Co.'s transmitters which you tested at the Brooklyn Navy Yard, and also the Wireless Specialty Apparatus Co.'s receivers known as the I-P-76 type, about which you have testified?

* * * * * * *

Answer. This drawing (P. Ex. 87) which I produce, entitled "Wireless Specialty Apparatus type transmitting station and receiving station," is a correct elementary diagram of the transmitting and receiving apparatus in question. On the drawing, both the receiver and the transmitter, are shown connected to an antenna *f*, although of course these antennae were not supplied with the equipment. The transmitting equipment consisted of a variable connection 1 from the antenna to a loading coil *g* and a variable connection 2 from this loading coil to the secondary of an oscil-

lation transformer d^1. The lower end of the oscillation transformer secondary was connected to the earth E. The primary of the oscillation transformer d was inductively related to the secondary d^1 and was in series with a quenched gap G and a condenser e. The connection from the quenched gap G to the oscillation transformer primary d was made by means of a variable contact 3. Connected across the condenser e there was a transformer secondary, the primary of the transformer C being energized by the generator of a motor generator set A though a telegraph key b. The receiving sets known as the type I-P-76 were all alike, so far as the elementary wiring diagram is concerned. The difference between 1912, 1913, and 1914 models was merely a question of mechanical design and refinement. These receivers consisted of a variable contact 4 from the antenna f to a loading coil g^1. A second variable contact 5 from the loading coil to the oscillation transformer primary j^1 and a third variable contact 6 from the oscillation transformer primary to the earth E. The secondary of this oscillation transformer j^2 was inductively coupled to the primary and was in series with a variable condenser h^1, the connection between the variable condenser h^1 and the oscillation transformer secondary j^2, being accomplished by the variable contact 7. In series across the variable condenser h^1, there was a crystal detector T and a small stopping condenser j^3. Across this stopping condenser was connected a pair of telephone receivers a portion of this circuit consisting of a potentiometer P, this potentiometer being connected across a local battery B.

The method of operating the transmitter would be as follows:

Before the equipment could be used to send radiograms it would be necessary for the operator to make certain adjustments. The Navy Department has certain conventional wave lengths which they use. The operator would proceed by the use of a wave meter to adjust the variable contact 3 so that the wave length in the primary circuit e, G, d would [fol. 236] have the desired value. In the actual transmitter the variable contact 3 consisted of several contacts all adjustable and so connected to a switch that any one could be chosen. The operator would then set the contact 2 in such a position as to provide sufficient inductance for proper coupling in the oscillation transformer secondary d^1 and would then vary the position of the contact 1 on the load-

ing coil *g* until the two circuits *e*, G, *d* and *f*, A, *g*, d^1 were in resonance with each other, thus obtaining a maximum current in the antenna *f*. It is to be noted that the variable contacts 1 and 2 also consisted of several contacts, similarly connected to a switch, so that any of these contacts might be chosen, this switch being driven by the same handle and operating simultaneously with the switch controlling the contact 3 in the primary circuit. Thus the complete transmitter was adjusted to several different wave lengths, in accordance with the Navy convention, and could subsequently be changed at will to emit any one of these wave lengths. The chief feature of the apparatus in question was this wave-length changing switch and the means by which the proper tuning of the several wave lengths in the primary and secondary circuits could be accomplished.

The type I-P-76 receiving sets were operated as follows:

By including practically all of the inductance in the oscillation transformer secondary j^2 the operator would be able to hear almost any incoming signal. When a signal which it was desired to read was so heard, the operator would adjust the variable contacts 4, 5, and 6 on the loading coil g^1 and the oscillation transformer primary j^1 so that this circuit would be in resonance with the incoming signals. He would then proceed to adjust the variable contact 7 on the oscillation transformer secondary j^2 and the variable condenser h^1, so as to produce resonance between this and the primary circuit, thus obtaining a maximum response in the telephones R. The crystal detector T would require to be adjusted to a sensitive point, the surface of the crystal varying greatly in this respect, and the tap on the potentiometer P would also be adjusted to produce the best response in the telephone R.

* * * * * * *

13. Question. Does your drawing and description of this I-P-76 receiver apply and are they correct with respect to the 1912, 1913, and 1914 models or do they relate to only one particular model?

Answer. To the best of my information and belief the drawing and my description of it apply equally to all three models of the type I-P-76 receiving set. The 1912 receiving set was, of course, the first one I saw and when samples of the new models were sent to the New York office in 1913 and

1914 my colleagues and I had the opportunity of examining them and noticing the changes which had been made. These changes consisted entirely of new arrangements of the component parts of the set and different construction of the parts themselves and of the switches by which they were adjusted.

Mr. Peters: I offer in evidence the drawing referred to and request that the same be marked "Plaintiff's Exhibit No. 87, drawing, Wireless Specialty Apparatus Co. apparatus."

[fol. 237] 14. Question. I show you a pamphlet entitled "Wireless Specialty Apparatus Co., Instructions for I-P-76 set." Do you recognize this pamphlet? And if so, what is it?

Answer. I do recognize this pamphlet; it was, as the title states, a book of instructions supplied with the receiving sets in question and intended as a guide to the operator for using the set. Copies of this pamphlet were always on hand at the New York office of the company. This pamphlet was revised and reprinted each year, so as to describe the new model of the receiving set.

Mr. Peters. I offer the pamphlet referred to in evidence, and request that the same be marked "Plaintiff's Exhibit No. 87a, Wireless Specialty Apparatus Co., Instructions for I-P-76 set."

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15. Question. I now call your attention to plaintiff's Exhibit No. 55, a contract by the Wireless Improvement Co., dated June 5, 1913, and which calls for the delivery at the U. S. Naval Radio Station, Radio, Va., among other items of "Item 1, 1 5-kw. high-frequency quenched-gap break-key motor generator, radio transmitting set, complete." What, if anything, do you know with reference to the manufacture and delivery of this apparatus?

Answer. I assisted in the design of this particular equipment; was present at the factory while it was being constructed and saw it packed for shipment to the Naval Radio Station at Radio, Va.

16. Question. Have you prepared and will you produce a drawing showing schematically the transmitting set in question?

Answer. I produce this drawing entitled "Wireless Improvement Co. type transmitting station." (P. Ex. No. 88.)

17. Question. Will you please describe this Wireless Improvement Co. set?

Answer. Although of entirely different mechanical design and arrangement, the fundamental wiring arrangement differs from that of the Wireless Specialty Apparatus type in only one essential particular, namely, the variable contacts 2, shown on the oscillation transformer secondary d^1 of the Wireless Specialty Apparatus Co. type, was not supplied or used on the Wireless Improvement Co. type. It is also to be noted that the wave-length switch arrangement on the Wireless Improvement Co. type—that is to say, on the 5-kw. transmitter mentioned in the contract—was not as complete as the wave-length switching device of the Wireless Specialty Apparatus type, that is to say the two 5-kw. transmitting sets which I saw and tested at the New York Navy Yard. This wave-length switch is not shown on either of these drawings, and it is to be noted that in both cases provision was made for accurately adjusting both the primary and antenna circuit, so as to produce resonance between the two, and thus obtain a maximum current in the antenna.

18. Question. Describe briefly the mode of operation of this Wireless Improvement Co. transmitter.

Answer. The adjustment and method of operation of his transmitter differed in no essential particulars from the method given for the Wireless Specialty Co.'s type.

[fol. 238] 19. Question. Please state what each of the elements shown on your Wireless Improvement Co. drawing represents.

Answer. *a* is a motor generator, *b* is a transmitting key, C is a power transformer, *e* is a condenser, G is a quenched spark gap, *d* is the primary of the oscillation transformer, d^1 is the secondary, *g* is the loading coil, *f* is the antenna, and E the earth connection.

Mr. Peters. I offer in evidence the drawing referred to by the witness and request that the same be marked "Plaintiff's Exhibit No. 88, drawing, Wireless Improvement Co. apparatus."

20. Question. What do you know with reference to the purchase by the U. S. Navy of apparatus from Emil J. Simon?

Answer. At the time of the organization of the Wireless Improvement Co. Mr. Simon was engaged by them as engineer. I worked with Mr. Simon for two years and over in the design and production of wireless transmitting equipment. The major part of this time was occupied in developing a ½-kw. equipment for use on submarine vessels. At the end of this period Mr. Simon left the Wireless Improvement Co. and proceeded to build and sell to the Navy Department ½-kw. transmitting sets of substantially the same design as those produced by the Wireless Improvement Co.

20a. Question. Have you seen any of these Simon transmitting sets at Navy stations; and if so, when and where?

Answer. The first low-powered wireless transmitter which Mr. Simon produced was built while he was with the Wireless Improvement Co. and was subsequently installed at the New York Navy Yard on the submarine *G-1*. It was found necessary after the set had been installed to provide it with an extra loading coil in order that its wavelength range might be increased. I visited the *G-1* at this time, then in dry dock at the New York Navy Yard; saw the transmitting set in question, and assisted in installing the additional loading coil. This was in 1913.

After Mr. Simon had left the Wireless Improvement Co. my duties required frequent visits to the New York Navy Yard, and on two of these visits I saw one ½-kw. equipment built by Mr. Simon in the radio laboratory at the navy yard. On one of these visits one of these sets was actually under test, and on another visit I saw what was probably 20 of these equipments lined up in the corridor awaiting test. This was in 1915.

21. Question. Have you prepared a drawing of the Simon transmitter which you state was supplied to the Navy? And if so, will you please produce the same and describe the transmitter?

Answer. I produce this drawing, entitled "Simon type transmitting station." (P. Ex. No. 89.) While Mr. Simon's transmitter differed materially in size and mechanical design with the two 5-kw. Wireless Specialty transmitters, which I have described, it will be noticed by comparison of the drawings that the fundamental wiring diagrams of the two types of transmitter differ in only one essential particular, namely, that in the Simon type the secondary of the transformer C is connected across the

quenched gap G instead of across the condenser c, as in the Wireless Specialty type. It is well known that the processes taking place in the transmitter are entirely unaffected by changing the transformer secondary connection from one position to the other, and in Mr. Simon's transmitter the choice was perfected by the mechanical arrangement of the parts.

* * * * * * *

[fol. 239] 22. Question. Please describe the mode of adjusting and operating this Simon transmitter.

Answer. While I am not familiar with the mechanical features which Mr. Simon employed to accomplish the various adjustments of the transformer set after he left the Wireless Improvement Co., I can state that the method of adjusting and operating this equipment would differ in no essential particular from the method which I have given for the adjustment and operation of the Wireless Specialty apparatus or Wireless Improvement Co. type. The Wireless Improvement Co.'s and Mr. Simon's ½-kw. transmitters were provided with five and in some cases six wave lengths—that is to say, points on a wave-length switch—but this device did not affect the necessity of adjusting the primary circuit with a wave meter to each of the desired wave lengths and then adjusting the antenna circuit to resonance with the primary circuit for each of these wave lengths.

* * * * * * *

24. Question. Did you ever examine any Simon sets supplied to the Navy by him sufficiently to ascertain the apparatus and methods employed for tuning?

Answer. On the occasions which I have mentioned, when I saw Mr. Simon's sets at the New York Navy Yard, my examination of the equipment was not close. I did, however, identify the various parts of the set and the wave-length switching and tuning mechanism, which I referred to in my description of the method of operating the set.

25. Question. Please now refer to the drawing and state what adjustments were provided in the set for tuning the circuits.

Answer. Since my answer to this question must involve to a greater or less degree the purely mechanical features of the equipment, I can only answer with reference to the

equipment which I have stated that I saw on test at the navy yard. The twenty-odd equipments which I saw later were of a different type, and I am not in a position to state definitely what the mechanical features of the tuning mechanism were. On the first set, however, the variable contact 3 shown in the drawing consisted actually of five leads connected to an equal number of points on a wave-length switch, these leads having clips for connecting to points on the primary of the oscillation transformer *d*. The variable contact 2 shown on the drawing consisted of a single lead connected to the end of the loading coil *g* and arranged to be connected onto the secondary of the oscillation transformer d^1 at any suitable point. The variable contact 1, shown in the drawing, consisted actually of five leads similar to those in the primary of the oscillation transformer, similarly connected to an equal number of points on a switch and similarly arranged to be connected each to a suitable point on the loading coil *g*. The switch arms on the two switches mentioned, namely, the switch on the [fol. 240] oscillation transformer primary, and the switch on the loading coils were both actuated simultaneously by a single front of board-handle. In adjusting the equipment it was first necessary to adjust the position of each of the leads corresponding to the variable contact 3 shown in the drawing by the use of a wave meter to give the desired wave length in the oscillation transformer primary, and then to adjust the position of each of the leads represented by the variable contact 1, shown in the drawing, so as to produce resonance between the closed oscillating circuit *d*, *e*, G and the antenna or radiating circuit *f*. *g*. d^1, E for each of the desired wave lengths.

Mr. Peters. I offer in evidence the drawing referred to by the witness, and ask that the same be marked "Plaintiff's Exhibit No. 89, drawing, Simon apparatus."

26. Question. Plaintiff's Exhibit No. 60, contract of September 21, 1912, with the Wireless Specialty Apparatus Co. calls for receivers furnished with standard perikon and silicon arsenic detectors. Plaintiff's Exhibit No. 62, contract of October 14, 1912, with the same company, calls for receivers containing perikon and pyrone detectors. Are you familiar with these types of detectors of the Wireless Specialty Apparatus Co.?

Answer. Yes, sir.

27. Question. Will you please briefly describe the elements of these detectors and their construction?

Answer. These detectors consisted either of a single crystal or of two crystals of certain minerals. The perikon detector consisted of zincite and chalcopyrite. The pyrone detectors consisted of iron pyrites and the silicon-arsenic of silicon and arsenic. The detectors were mechanically arranged so as to produce a contact between a single crystal and a small metal wire or between the two crystals in the case of the double-crystal detectors. Since the operation of the device depended upon a delicate adjustment of this contact, various mechanical arrangements were employed in different types of detectors in order that the adjustment might be easily and accurately made.

28. Question. Will you endeavor to procure one of the types of Wireless Specialty Co. detectors referred to in your last answer and forward it to the commissioner who is taking this testimony, with a letter stating that it is such detector, and of the type referred to in your last answer.

Answer. I will be glad to.

* * * * * * *

29. Question. I hand you two paper-covered pamphlets, entitled "Radiotelegraphy, U. S. Signal Corps, revised May, 1915," and one revised October, 1916, and one canvas-covered book entitled "Circular No. 1, Office of the Chief Signal Officer, 1914, Radiotelegraphy, U. S. Signal Corps, 1914." Please state if you know what these publications are.

* * * * * * *

Answer. These pamphlets, like similar booklets issued by the Navy Department were issued to department operators [fol. 241] in charge of wireless-telegraph equipment and were intended as an introduction to the study of radiotelegraphy and as a guide to installing and operating radio equipment. These booklets were also issued to the general public and formed part of the library at my disposal while I was with the Wireless Improvement Co.

30. Question. If you know, please state by whom they were issued?

* * * * * * *

Answer. Copies of the pamphlets could be obtained through the office of the Chief Signal Officer, and I therefore assume they were issued by that office, since the title so states. So far as I know, they could not be obtained from any other source.

* * * * * * *

31. Question. Can you state what different branches, departments, or service of the Government since June, 1910, made use of wireless telegraph apparatus?

* * * * * * *

Answer. I am quite sure that the Navy Department has used a large quantity of wireless-telegraph apparatus, and I also know that the Treasury Department and the Navy Engineering Department and the Signal Corps of the Army use wireless-telegraph apparatus.

32. Question. I call your attention to plaintiff's Exhibits Nos. 37, 38, 39, and 40. Will you please look at these exhibits and state whether or not you are familiar with any of them; and if so, what they are?

Answer. The four exhibits in question are specifications issued by the Navy Department to contractors wishing to bid on schedules calling for the construction and delivery of wireless-telegraph sets. Exhibit No. 37, the Navy designation of which is 16-T-5, is dated May 10, 1910, and antedates my connection with the production of apparatus for the Navy. Exhibits 38, 39, and 40, however, are well known to me, and I have designed and built sample sets to be delivered to the Navy and have designed and built sets under contract with these specifications as a guide. The specifications enter into the construction of equipment in great detail and leave very little to the designer's discretion, and in all cases they call for equipments, both transmitting and receiving, in which an open or radiating circuit is inductively coupled to a closed oscillating circuit.

33. Question. In what connection were the sample sets, referred to in your last answer, delivered to the Navy? Was it in connection with bids made under the specification referred to, or what is the practice in that respect?

* * * * * * *

Answer. Since my connection with the production of radio equipment for the Navy—that is to say, since June, 1913—the practice has been as follows:

The Navy Department would send to all different contractors what was known as the schedule. This schedule would call for the delivery at some navy yard, usually New York Navy Yard, of a definite quantity of wireless-telegraph sets, either transmitters or receivers, or accessories, and sometimes of all three. The schedule would state that the apparatus was to be built under specifications issued by the Navy Department, and the number of these specifica- [fol. 242] tions would be given. The schedule would also call for delivery of the apparatus in question a definite number of days after the date of the contract, and where possible would require each contractor to submit a complete sample equipment to a designated navy yard for competitive test prior to the award of the contract. In cases where a particular contractor had supplied under previous contract satisfactory apparatus of the same size and design, it was not necessary for him to submit a sample under the new schedule.

Mr. Cosgrove: Plaintiff's counsel offers in evidence the "Radiotelegraphy" for the years 1914, 1915, 1916, identified by the witness in answer to Q. — and requests that the same be marked "Plaintiff's Exhibits Nos. 90, 91, and 92, Radiotelegraph, 1914, 1915, 1916," respectively.

Cross-examination.

By Mr. Workman:

* * * * * * *

34. Cross-question. As I understand it you were a student in Columbia University up until 1913. Is that correct?

Answer. Yes, sir.

35. Cross-question. At what time in the year did you finish at Columbia University?

Answer. I received my degree early in June, I believe it was on the 6th.

36. Cross-question. And after leaving the university, where did you first go?

Answer. I took a short holiday and went to work for the Wireless Improvement Co., about the 1st of July, 1913.

37. Cross-question. What was it, the usual four-year course, or more, that you took at Columbia University?

Answer. At the time, the course in electrical engineering was a four-year course. I entered the university in 1908,

but was compelled to leave in January, 1910, and when I returned to college in the fall, I repeated the studies of the sophomore year.

38. Cross-question. How long did you remain with the Wireless Improvement Co.?

Answer. Until October 1, 1916.

39. Cross-question. And then did you go with the Wireless Specialty Apparatus Co.?

Answer. No, sir; I went with the Marconi Wireless Telegraph Co.

40. Cross-question. Then the Wireless Improvement Co. and the Marconi company are the only companies that you have been employed with?

Answer. That is not entirely true. When I left college in 1910, I worked during the spring and summer with the DeForest Radio Telephone & Telegraph Co.—during the following summer, that is the summer of 1911, I worked with the National Electric Signaling Co. During the summer of 1912, I worked for the Wireless Improvement Co. After my graduation from college and while I was with the Wireless Improvement Co., I did considerable work for the Wireless Specialty Apparatus Co. on a time basis, that is to say, when they had work which required the attention of an engineer in New York City, Colonel Firth, being second vice president of the Wireless Specialty Apparatus Co., [fol. 243] would direct me to take charge of the work and the Wireless Specialty Co. paid me for this work by the hour.

41. Cross-question. All your work with these various companies was in and around New York City, wasn't it?

Answer. It was chiefly in New York City, although of course I did make business trips to Washington.

42. Cross-question. When you said that the radio telegraph sets of plaintiff's Exhibit No. 60, contract between the Wireless Specialty Apparatus Co. and the United States, were built in Boston, you were guessing weren't you?

Answer. I did not see these sets actually in construction at the Wireless Specialty Apparatus Co.'s factory in Boston. The New York office of the company was constantly in telegraphic communication with the Boston office and particularly so at the time of shipment of these equipments, and I am therefore willing to testify that they were built there.

43. Cross-question. You had no connection with the packing up and shipping of wireless-telegraph sets of the Wireless Specialty Apparatus, did you?

Answer. Not with the shipment of transmitters, but very frequently receiving sets were held in stock at the New York office and I myself have assisted in packing and shipping several from that place.

44. Cross-question. Was the Wireless Improvement Co. and the Wireless Specialty Apparatus Co. all the same concern? Or what was the connection between the two?

Answer. The Wireless Improvement Co. was organized and owned by Col. John Firth. Whether this company was ever legally incorporated I do not know. I believe that the Wireles Specialty Apparatus Co. was also organized by Colonel Firth and was owned by him at one time. At the time of my connection with the Wireless Improvement Co., however, Colonel Firth signed himself on checks and other documents as the second vice president of the Wireless Specialty Apparatus Co. I might also state that at the time when Mr. Simon left the Wireless Improvement Co., in March, 1915, Colonel Firth turned over to the Wireless Specialty Apparatus Co. the designs and drawings which had been produced by the Wireless Improvement Co. and that the Wireless Specialty Apparatus Co. proceeded to build and sell wireless equipment from these designs and drawings. I was therefore not entirely correct in saying that I had never been connected with the manufacture and shipment of transmitters sold to the Navy by the Wireless Specialty Apparatus Co., because when the designs and drawings were turned over, as I have stated, we built in New York City several ½-kw. transmitters for the Wireless Specialty Apparatus Co. and some of these transmitters were eventually sold to the Navy.

45. Cross-question. What date was it, if you remember, when Mr. Simon left the Wireless Improvement Co.?

Answer. March, 1915.

46. Cross-question. Are we to understand from your testimony that the Wireless Improvement Co. up to the time Mr. Simon left it at any rate was handling the apparatus of the Wireless Specialty Apparatus Co.?

[fol. 244] Answer. No, sir; the Wireless Improvement Co. never handled the apparatus of the Wireless Specialty Co., but Colonel Firth, who acted as New York agent for the Wireless Specialty Co., did handle their apparatus.

There is only one exception to this; that is, that in some cases the Wireless Improvement Co. supplied Wireless Specialty Apparatus Co. receiving sets with their transmitting sets, purchasing these from the Wireless Specialty and reselling them to the customers.

47. Cross-question. How are you able to state that delivery under contract, plaintiff's Exhibit No. 60, with Wireless Specialty Co. was not made until a year later than the date of the contract?

Answer. I have seen the copy of the contract which forms the exhibit mentioned and note that it is dated 1912. I know that the acceptance tests of these two sets were made in 1913, having assisted in these tests myself. Apparatus of this nature is entirely special, and for two equipments of this size and complexity one year is quite usual.

48. Cross-question. Do you intend to say that you are familiar with all the wireless apparatus that the Wireless Specialty Co. has furnished the Government or the Navy?

Answer. Not at all. The two 5-kw. transmitters in question are the only transmitting equipments built by the Specialty company in their own factories and sold to the Navy Department which I have ever seen.

49. Cross-question. But as you didn't see this transmitting apparatus, how do you know it was built by the Wireless Specialty people at all; how do you know they didn't purchase it from some one else?

Answer. Which transmitting apparatus is referred to in this section?

50. Cross-question. We have all the time been talking about the contract of 1912 with the Wireless Specialty Apparatus Co., plaintiff's Exhibit No. 60.

Answer. I did see the apparatus called for in the contract. The address of the Wireless Specialty Co. is given in the contract as 81 New Street, New York, this being the office of Colonel Firth and the place where I worked for the Wireless Improvement Co. I had direct knowledge of the award of this contract, and, as I have already stated, assisted in the tests of the sets after they were delivered.

51. Cross-question. In your answer to Q. 5 you stated you were not familiar with the receiving apparatus mentioned in this contract, and that it was probably built in Boston and shipped directly to Washington. This seems to be quite different from what you have just stated. Do you wish to clear up this contradiction?

Answer. My answer to the preceding question applied only to the transmitting sets, the receiving sets being only a small portion of the contract. It may very well be that the receivers called for in this contract were delivered long before the transmitting sets were. This I do not know, but the delivery on a contract was, of course, not completed until the transmitters had been delivered and accepted by the Navy.

52. Cross-question. Why do you speak of the transmitters of this contract as two 5-kw. transmitters? What is there in the contract that specifies this power of apparatus?

[fol. 245] Answer. This is the designation by which they would be known to a wireless man. This is the normal rating of the equipment which would be indicated on the power-measuring device supplied with the set, and the contract under item 1 calls for a 5-kw. radiotelegraph set, complete.

53. Cross-question. None of these wireless apparatus that you have mentioned in your direct deposition included any antennae, did they?

Answer. They generally did not.

54. Cross-question. And as to the receiving sets which you have spoken of in your direct deposition, you have no knowledge, have you, as to what transmitting sets were used in connection with them?

Answer. No; I have not.

55. Cross-question. As a matter of fact, most receiving sets supplied to the Navy may be and are used to receive from various other makes and types of transmitting apparatus. That is correct, isn't it?

Answer. It is correct, but it is quite frequent to use the receiving set supplied with any transmitter for making the original adjustments on the transmitter, in which case it is used in exactly the same manner as it would be to receive a signal from a distant transmitter.

56. Cross-question. As I understand it, you did no work in constructing the apparatus under either of the contracts you have referred to as plaintiff's Exhibits Nos. 60, 62, or 63?

Answer. No; I did not, except that on the two transmitters referred to in Exhibit 60 several parts became inoperative during test and had to be replaced with new parts, and my assistants and I did the work in putting these parts in their proper places.

57. Cross-question. What does type I-P-76 mean? Do these letters and figures have any particular significance?

Answer. The letter "P" in the type number is, I believe, a reference to Doctor Pickard, who, I understand, designed these receiving sets. The letter "I" has no special significance, so far as I know, and was often read as "one." The remaining part of the type numbers is a serial designation to distinguish the apparatus from other kinds.

58. Cross-question. This drawing of the Wireless Specialty Apparatus type that you produced—did you make this yourself?

Answer. No, sir; but it was made under my direction.

59. Cross-question. Made from your memory?

Answer. The fundamental wiring diagram of a wireless transmitter or receiver is as familiar to a wireless man as his own signature.

60. Cross-question. And out of the numerous types he has them all at his finger ends and can draw any one of them as easy as he can write his signature?

Answer. It is only necessary to remember that such and such a set had such and such an arrangement for changing connections between the various parts in order that this may be accurately shown on the drawings.

61. Cross-question. Did you put the reference letters on this drawing?

[fol. 246] Answer. The reference letters used on this drawing were chosen at the suggestion of counsel in order that all the various drawings used in this case might be alike in this respect, thus making reference to them more easy.

62. Cross-question. Why do you call *g* a loading coil and do not call *d'* a loading coil?

Answer. The coil *d'* is known as the secondary of the oscillation transformer because it is placed in the set near the primary of the oscillation transformer; that is to say, near the part of the equipment in which the oscillations are actually produced. It is so placed in order that it may absorb or take up these oscillations and is arranged so that its nearness to the primary coil may be varied at will. The coil *g*, however, is not placed near the primary of the oscillation transformer and is not arranged to be inductively related thereto. Its sole purpose is to increase the electrical constants of the open radiating circuit in such a way as to make possible an adjustment for resonance between these two circuits, the constants of the radiating circuit without the

use of this extra coil in general not being such as to produce this condition of resonance. It is therefore known as a loading coil.

63. Cross-question. If the coil *g* were placed as you express it near the primary of the oscillation transformer and was arranged to be inductively related thereto you would not have called it a loading coil, would you?

Answer. No. It becomes a loading coil only when it is necessary, as I have stated, to increase the constants of the circuit in order to produce resonance. It very frequently happens that when adjusting to a short wave length the constants of the circuit, without the use of a loading coil, may be made correct for resonance, but since all transmitters are arranged to be used at longer wave lengths, the loading coil is supplied. The purpose of arranging this so that it is not inductively related to the primary is to make the adjustments of the set simpler. The oscillation transformer secondary being used to absorb the energy, or as we say to produce coupling between the two circuits and the loading coil being used without directly affecting the degree of this coupling to tune the circuit to the period of the primary circuit; that is to say, to produce resonance between the two.

64. Cross-question. The constants of the circuit that this what you have called loading coil affects is the inductance of the circuit, isn't it?

• • • • • • •

Answer. Chiefly, yes; although no inductance can be built which has no capacity effect.

65. Cross-question. And you wouldn't call *d'* in this Wireless Specialty Apparatus drawing an inductance coil?

• • • • • • •

[fol. 247] Answer. I would call all the coils shown in this drawing except possibly the coil marked, which is a potentiometer coil and presumably has no inductive effect, inductance coils, if that were a proper name for any of them. They are more usually referred to by the names which I have given you. They all, however, possess inductance, and also to a limited degree the property known as capacity.

66. Cross-question. You can't have an inductance coil in the circuit without affecting the inductance constant of that ci-cuit, can you?

• • • • • • •

Answer. So far as I am able to state, without referring to the extensive literature on the subject, you can not.

67. Cross-question. There is no difference, is there, between the apparatus as you have represented it in this drawing of the Wireless Specialty Apparatus and the drawing you produced of the Simon type?

Answer. There is the one difference which I mentioned, namely, that in the Simon set the secondary of the transformer is connected across the quenched spark gap instead of across the condenser as in the Wireless Specialty type.

68. Cross-question. To which transformer are you referring in this last answer?

Answer. I am referring to the power transformer C, which is a device with an iron core and is the seat of currents whose frequency of alternation is 500; the frequencies present in the oscillation transformer are of a different nature and of a much higher order.

69. Cross-question. In both the Wireless Specialty Apparatus and the Simon type apparatus spark gap G is in the closed oscillation circuit, isn't it?

Answer. Yes, sir.

70. Cross-question. And it makes no difference whether this spark gap is as shown in the Wireless Specialty Apparatus type or whether it is as shown in the Simon type?

Answer. No, sir.

70a. Cross-question. Notwithstanding the fact, as you say, that the oscillations are of a very different order in the circuit of the oscillation transformer *b* than they are in the circuit of the transformer C?

Answer. No, sir.

71. Cross-question. Then you can tell by merely looking at the apparatus whether the spark gap G for example is in the position shown in the Wireless Specialty Apparatus sketch or whether it is in the position shown in the Simon type?

Answer. Yes, sir.

72. Cross-question. And you don't have to look at the wiring on these sets to find that out?

Answer. To look at the set is to look at the wiring of it.

73. Cross-question. You mean that all this wiring that is shown on these various sketches is apparent at a glance at a wireless apparatus?

Answer. The secondary of the power transformer and beyond, that is to say, through the gap, condensers, oscilla-

tion transformer, and loading coil, is all high tension. The [fol. 248] conductors are therefore almost invariably without insulation and are spaced well apart so that the circuit of which they form a part can be very easily traced.

74. Cross-question. Isn't it a fact that an ordinary wireless set consists of a number of instruments on a board or a sheif and you can't see their connections unless you carefully trace them out?

Answer. Just what would be considered an ordinary wireless set I do not know, but in the specific cases in question it was a matter of no difficulty to notice how the circuits were made.

75. Cross-question. There aren't any wireless sets that you are aware of, are there, that don't have oscillation transformers?

• • • • • • •

Answer. There have been many such sets built and I presume some of them are still in existence.

76. Cross-question. What kind are these you have just referred to?

• • • • • • •

Answer. It would be like trying to name all the other makers of automobiles than the Ford.

77. Cross-question. Do you know of any such that have been in practical use for transmitting signals in a practical way?

• • • • • • •

Answer. None of commercial or military importance except such stations at Sayville and Tuckerton, where high-frequency generators have been used.

78. Cross-question. Have been used for actual transmission of signals or just experimentally?

• • • • • • •

Answer. For the actual transmission of intelligence.

79. Cross-question. And these high-frequency generators were used with spark gaps, were they?

• • • • • • •

Answer. No, sir.

80. Cross-question. Well now let us confine ourselves to the kind of wireless apparatus that you have referred to in

your direct examination and in the drawings you have produced. Do you know of any wireless apparatus that employed a spark gap of some kind or other that didn't have an oscillation transformer?

* * * * * * *

Answer. Yes, sir.

81. Cross-question. Well, what type of wireless apparatus do you refer to in your last answer?

* * * * * * *

Answer. A great many amateur stations have been so constructed, and if I am not mistaken apparatus which would answer this general description can be purchased from the amateur supply people to-day.

82. Cross-question. In the class of apparatus you have just referred to, how are the oscillations got into the radiating circuit, as you call it?

* * * * * * *

[fol. 249] Answer. There is but one circuit in these transmitters and the antenna forms a part of it, and the oscillations, although of an entirely different nature from those produced in the transmitter which I have described, are produced in that circuit.

83. Cross-question. Is the amateur apparatus you have just referred to merely an educational apparatus or is it used for practical emission of signals intended to be received at a distance?

* * * * * * *

Answer. It is actually used for the transmission of signals.

84. Cross-question. What are the constants that you have referred to in the circuits of wireless apparatus, as, for example, in answer to cross-question 62?

* * * * * * *

Answer. I used the term constants in that case to mean what we call the inductance and capacity of the circuit.

85. Cross-question. Is it a fact that any oscillating circuit must have inductance and capacity in it in order to be such a circuit?

* * * * * * *

Answer. Yes, sir; so far as I know.

86. Cross-question. Then, any wireless apparatus would have in its transmitting portion an inductance coil corresponding to the coil *d* marked on these drawings?

* * * * * * *

Answer. No, sir.

87. Cross-question. Isn't that coil *d* one of the constants you have referred to as being necessary in an oscillating circuit; isn't it a fact that it is the inductance of that circuit that includes it?

* * * * * * *

Answer. It is true to be sure that the coil *d* is the seat of a portion of the total inductance of the circuit of which it forms a part, but it is not true that the circuit could not be made the seat of oscillations if the coil *d* were removed.

88. Cross-question. You have spoken of tuning on your direct examination. What do you wish to be understood as meaning by tuning with reference to the apparatus in these various sketches you have produced?

Answer. The process of adjusting the closed circuit so that it will have a definite desired frequency and of adjusting the open or radiating circuit so that it will have independent of the closed circuit the same frequency. Since the theory of this process is very involved, my answer is as definite and complete as any brief statement could be made.

89. Cross-question. Am I correct in thinking that a circuit for emitting intelligible signals by wireless telegraphy requires that that circuit have a definite number or a predetermined number of so-called electrical oscillations in a given unit of time?

* * * * * * *

Answer. No, sir.

[fol. 250] 90. Cross-question. I will repeat the question with the qualification that the circuit referred to is intended to transmit or receive what is known, if I am correct, as spark signals.

* * * * * * *

Answer. The same answer is still correct.

91. Cross-question. Then you can have in a practical wireless apparatus a circuit at the transmitting station that

radiates or sends out oscillations irregular in period and can transmit intelligible signals therewith. Is that correct?

•   •   •   •   •   •   •

Answer. I should prefer to say complex rather than irregular.

92. Cross-question. Then if that be true your tuning is not at all necessary, is it, in wireless apparatus, and there is no reason for having adjustable contacts 1, 2, 3, etc., shown on your drawings?

•   •   •   •   •   •   •

Answer. It is entirely necessary if the maximum result for a given expenditure of energy is to be obtained.

93. Cross-question. Isn't the term "resonance," which you have employed, practically the same thing as tuning?

•   •   •   •   •   •   •

Answer. The two terms are not entirely synonomous, one referring to a process and the other to the result produced by it.

94. Cross-question. Isn't it a fact that unless your receiving circuit, for example, is tuned to the oscillations emitted from the sending stations, you will get no intelligible signals from that station?

•   •   •   •   •   •   •

Answer. No, sir.

95. Cross-question. Isn't it a fact that by certain adjustments in your receiving apparatus you can exclude the reception of certain incoming oscillations from a sending station?

•   •   •   •   •   •   •

Answer. Not always and seldom entirely.

96. Cross-question. Isn't it a fact that the Government has prescribed certain definite oscillation frequencies for Government signals or certain definite wave lengths to be used by the Government only, and not to be used by private stations?

•   •   •   •   •   •   •

Answer. Yes, sir.

97. Cross-question. Then, isn't it a fact that tuning to receive wave lengths of definite frequency or definite fre-

quency of oscillations is necessary and involved in any wireless apparatus?

* * * * * * *

Answer. Desirable and beneficial, but not necessary.

98. Cross-question. You would not say it was a mere whim on the part of the Wireless Specialty Apparatus or of the Simon type of apparatus or of the Wireless Improvement Co. apparatus that the various contacts 1, 2, and 3 were made adjustable for tuning, would you?

Answer. The companies in question had no choice in the matter. The specifications issued by the Navy Department [fol. 251] and under which these equipments were built required that such provisions for tuning be made.

99. Cross-question. Do you mean to say that *in* apparatus supplied by these companies to private parties does not include any of these adjustments?

* * * * * * *

Answer. I have no definite knowledge that any of the companies mentioned sold wireless apparatus to private parties.

100. Cross-question. The only difference between the transmitting station of the Wireless Improvement Co. and that of the Wireless Specialty Apparatus Co., illustrated on the drawing you have produced, is that in the latter there is an adjustable contact 2 for the coil *b'*, whereas there is none in the Wireless Improvement Co. apparatus. Is that correct?

Answer. So far as the fundamental wiring diagram as exhibited in these two drawings is concerned; yes.

101. Cross-question. To make these last two drawings last referred to consistent, as you said was the intention putting the particular reference characters used on them, contact 2 in the Wireless Improvement Co. should be "3," should it not?

Answer. I believe that this change would help to make the drawing more consistent.

102. Cross-question. Just what do you mean by "fundamental wiring diagram" as applied to the apparatus supposed to be represented on these drawings? Do you mean that these drawings do not completely represent the apparatus referred to?

Answer. All wireless transmitters are machines or devices for converting electrical energy in some form which

is available into the form of electromagnetic waves. No single drawing could completely represent such a device, but a fundamental wiring diagram is a drawing showing diagrammatically those pieces of apparatus essential to the several transformations of energy required and the arrangement of the connections between them.

103. Cross-question. You described the operation of the Wireless Specialty Apparatus set represented on your drawing, and referring to the operation of the receiving set, would you state that any operator would proceed to make the adjustments as you have given them and in the order that you have given them, or would some operators adjust the different coils and condensers in a different order?

Answer. I personally have had very little contact with wireless operators. From their general reputation, however, I should say that the method by which they would make these adjustments would be entirely irregular and not capable of description which would be at all brief. The method given, however, is the method which I believe to be best suited for quickly obtaining satisfactory results with the apparatus in question. In this connection I would call attention to my answer to Q. —, in which I mentioned the involved nature of the theory of this process.

104. Cross-question. What is the purpose of the potentiometer P on the drawing of the Wireless Specialty Apparatus receiving station?

Answer. It is supplied in order that the detector may be adjusted to a condition of maximum sensitiveness.

[fol. 252] 105. Cross-question. Referring to your former answer concerning the ready identification of a wireless apparatus as to its wiring and circuits, I call your attention to Figure 99 in the 1913 edition of the Navy Manual of Wireless Telegraphy. Isn't this a clear representation of what a wireless set looks like?

Answer. No, sir. It represents what wireless sets used to look like, but none of the apparatus referred to in my testimony had such an appearance.

106. Cross-question. Well, isn't what that photographic reproduction shows in that 1915 manual, Figure 99, about what one sees when he looks into the wireless operator's room at a wireless station, namely, a set of instruments on a table or against the wall?

Answer. No, sir.

107. Cross-question. Is none of the apparatus that you have shown on these drawings which you have produced inclosed in casings with merely binding posts visible?

Answer. The type I-P-76 receiving sets of whatever model were all inclosed in a cabinet and the wiring was concealed. I have, however, as already stated, had ample opportunity to dissemble these sets and examine their internal connections minutely. The transmitting sets referred to in my testimony were never inclosed and consisted in general of a panel supported on an angle-iron frame with the various parts described in the equipment mounted on a panel, and the high-tension wiring, which is indicated diagrammatically in my drawings, would be in plain sight and could be seen from the rear or from either side of the equipment.

108. Cross-question. The drawing of the Simon type apparatus represents only the transmitting apparatus. Was the Simon type apparatus that you saw in the radio laboratory at the navy yard also transmitting apparatus?

Answer. Yes, sir.

109. Cross-question. How are you enabled to state that the 20 of the Simon equipments that were lined up in the corridor awaiting test were in fact of the type represented in your drawing?

Answer. I had knowledge that Mr. Simon had been awarded a contract to supply these sets. I recognized them immediately as transmitters and saw a very conspicuous name plate, reading "Emil J. Simon," on each one of them.

Redirect examination.

By Mr. Cosgrove:

110. Redirect question. In your answer to XQ. 53 you state that none of the wireless apparatus referred to in your direct examination included any antenna. Was any of this apparatus intended and adapted for use with the antenna? If so, what means or construction were provided in or with the apparatus for combining the same with an antenna?

* * * * * * *

Answer. The specifications under which these equipments were built, namely, the specifications offered in evidence as

Exhibits 37, 38, 39, 40, give the electrical dimensions of the antenna with which these equipments were intended to be used, and the design of the equipment was in every case largely effected by these dimensions. Each set before shipment to the Navy Department and also after its delivery to them is tested with artificial antenna arranged to duplicate [fol. 253] the electrical dimensions of the antenna with which it is intended to be used. All these sets had a binding post usually located on what was called an antenna send-receive switch, which was marked to show that that was the place where the antenna was to be connected. The instructions supplied with the equipment told the operator to connect the antenna at this place. It is also to be noted that unless the equipment was so connected to antenna, either real or artificial, no oscillations could be produced in the secondary circuit.

111. Redirect question. About when was the Wireless Improvement apparatus referred to in your deposition and called for in plaintiff's Exhibit No. 55, contract of June 6, 1913, with the Wireless Improvement Co., shipped to the Navy radio station at Radio, Va.?

Answer. In October of the same year.

112. Redirect question. Is that station sometimes known as the Arlington Station?

Answer: Yes, sir.

Recross-examination.

By Mr. Workman:

113. Recross-question. On what do you base your statement that the apparatus of Exhibit No. 55, contract of June 6, 1913, was shipped in October of that year? Does your memory carry back some three or four years to a particular month for a particular shipment?

Answer. I have refreshed my memory by referring to notes which I personally made at that time.

The examination by counsel being concluded, the witness, in compliance with the rule of the court requiring him to state whether he knows of any other matter relative to the claim in question, and if he does, to state it, says he does not.

Deposition of Roy A. Weagant, for Claimant, Taken at New York, N. Y., on the 18th and 19th Days of July, A. D. 1917.

* * * * * * *

Roy A. Weagant deposed and said that his name is Roy A. Weagant; that his occupation is that of chief engineer of the Marconi Wireless Telegraph Co. of America; that he is 36 years of age; that his place of residence is Douglas Manor, Long Island; that he has no interest in said cause except to the extent of being an employee of the plaintiff company; and that he is not related to the plaintiff.

* * * * * * *

Direct examination.

By Mr. Cosgrove:

1. Question. What education, experience, and training have you had in the construction and operation of radio wireless telegraph apparatus?

Answer. I was educated at McGill University, Montreal, where I took the four years' course in electrical engineer-[fol. 254] ing. For the past five years I have been engaged in the design and construction of wireless telegraph apparatus for the plaintiff, Marconi company, and also in research and investigation work. For the past year and a half I have been chief engineer in the Marconi company. Prior to that time I was employed by the National Electrical Signaling Co., and my work with them consisted in designing and research work and general wireless telegraph work. I was employed by them for a period of about four years. Prior to that time I was engaged for some three years in other branches of electrical engineering work, during which time I was in the employ of the Westinghouse Electrical Manufacturing Co., of Pittsburgh, Pa., and of the DeLaval Steam Turbine Co. of Trenton, N. J. I am a fellow of the Institute of Radio Engineers, a member of its board of directors, and a member of the standardization committee.

2. Question. Will you please state what, if any, experience you have had in offering to supply and in supplying radio apparatus to the United States Government?

Answer. I have done a great deal of this sort of work and have made out and submitted to the Government a large

number of bids for wireless apparatus in accordance with specifications supplied by the Navy Department and Signal Corps, the Coast Guard Service, and the Department of Insular Possessions.

3. Question. Please examine the plaintiff's Exhibits Nos. 42, 43, and 44 and state whether you are familiar with them and what these exhibits are.

Answer. I have examined these plaintiff's Exhibits Nos. 42, 43, and 44 and find them to be specifications prepared by the United States Signal Corps covering wireless telegraph apparatus. I am quite familiar with the specifications, of which these are specimens and which are supplied by the United States Signal Corps to contractors for the purpose of securing bids on wireless telegraph apparatus.

4. Question. Have any of the departments of the United States Government, since June, 1910, manufactured radio apparatus? And if so, please state what departments and the sources of your knowledge and information as to such manufacture.

* * * * * * *

Answer. Two departments of the United States Government, to my knowledge, have manufactured wireless telegraph appartus during this period—namely, the Navy Department and the Signal Corps. I know that the Navy Department has manufactured wireless telegraph apparatus, because the Chief of the Bureau of Steam Engineering, in his report for the year 1915, on page 345, has so stated: also because Commander Todd, in the hearings of the Committee on Merchant Marine and Fisheries of the House of Representatives in relation to a bill to regulate radio communication in January, 1917, has so stated on page 20. As regards the apparatus made by the Signal Corps, I have been told by representatives of the Signal Corps that they did make certain apparatus, and I have been asked to consider the matter of building duplicate apparatus in the factory of the Marconi company.

* * * * * * *

[fol. 255] 5. Question. Have you ever seen any of the radio apparatus manufactured by the Navy Department of the United States on exhibition anywhere? And if so, please state when and where and under what circumstances you saw such exhibition.

Answer. Yes; I have seen apparatus manufactured by the Navy Department which was exhibited at the electrical show in the Grand Central Palace, New York City, some time during the winter of 1916-1917.

6. Question. Was the exhibit referred to in your last answer an official exhibit of the Navy Department's work?

Answer. I so understood it to be, as there were signs in the vicinity of the apparatus indicating that fact and my recollection is that there were name plates on the apparatus stating that it had been manufactured by the Bureau of Steam Engineering.

7. Question. Was the exhibit by the Navy Department at the Grand Central Palace installed or set up so that it was capable of operation?

Answer. Yes; it was.

8. Question. Did you examine or inspect the construction of this radio exhibit?

Answer. Yes; I did.

9. Question. Please briefly describe the construction of the exhibit by the Navy Department, which you inspected at the Grand Central Palace, the arrangement of the circuits and adjustments, producing and referring to any drawing you may have thereof, explaining the character of the drawing.

Answer. The apparatus which I saw comprised a complete receiving and transmitting equipment. I produce a drawing (P. Ex. No. 93), showing the circuit arrangement in schematic form, of the transmitter and receiver. Referring to the left-hand circuit, marked "Transmitting station": This consisted of an antenna *f*, a connecting lead therefrom marked A, a variable inductance or loading coil marked *g*, having variable contacts thereon, marked 1 and 1^a, a second inductance coil *d'*, having variable contact, such as 3, which constituted the primary of the oscillation transformer. Leading from this oscillation transformer primary was a connection to earth E. All of the above-mentioned elements formed the open-radiating circuit. In addition, there was a closed-oscillating circuit, comprising a spark G of the quenched-gap type, a condenser *c*, an inductance coil *d*, which constituted the primary of the oscillation transformed, and which was arranged in inductive and operative relation to the inductance coil *d'* in the open-radiating circuit. Attached thereto was a variable contact 2, which provided means for varying the

amount of this inductance in use at any time and consequently the period of this closed circuit. The transmitter also comprised a power transformer *c*, whose secondary or [fol. 256] high-tension terminals were connected to the condenser *e* and whose primary or low-tension terminals were connected through an operator's key *b* to an alternating current generator *a*. Both of the oscillation circuits referred to, namely, the open-radiating circuit, shown in black line, and the closed-oscillating circuit, or reservoir circuit, shown in red line, had the necessary means for adjusting the two circuits to the same time period.

Referring now to the diagram at the right, marked "Receiving station": The receiving apparatus comprised an antenna *f*, a connecting lead therefrom A, a condenser *h*, an inductance *j'*, a variable contact 5, and a connection to earth E. This circuit shown in black constituted the open radiating circuit, whose time period was adjustable as desired by means of the variable condenser *h*, and the variable inductance *j'*. Associated with the above-described circuit, was a second, comprising an inductance j^2, having thereon a variable contact 4, and a variable condenser *h'*. To the terminals of the condenser *h'*, were connected a detector T, a blocking condenser j^3. These elements constituted the closed oscillating circuit of the receiving system. Connected across the condenser j^3, was a telephone receiver R. The closed oscillating circuit of the receiver was so arranged as to be inductively coupled through the coil j^2 to the coil *j'* of the open radiating circuit, and by means of the variable elements, namely the variable condenser *h'* and the variable inductance j^2, its time period could be adjusted to be the same as that of the open radiating circuit.

10. Question. Will you briefly describe the operation of the apparatus referred to in your last answer and illustrated in the drawings produced by you and state what adjustments an operator would make in the normal working of the apparatus and for what purpose?

Answer. In the operation of the transmitting apparatus referred to, an operator first causes oscillations to take place in the close oscillating circuit marked in red; he then makes adjustments of the variable contact 2, until the time period or wave length is the desired one, as indicated by the usual measuring instrument known as the wave meter. He then makes adjustments of the contact 1, 1^a, 3, in the cir-

cuit shown in black, or open radiating circuit, until an indicating instrument in this circuit shows that a maximum current is flowing therein. He also makes further adjustments of the distance between the coils *d* and *d′* until the best spacing as shown by this same instrument is found. When he realizes this condition, the apparatus is tuned and the time periods of the open radiating circuit and the closed oscillating circuit are then identical. In adjusting the receiving apparatus, he makes adjustments of the condenser *h* and the contact 5 in the open radiating circuit shown in black of the contact 4 and the condenser *h′* in the closed reservoir circuit, until the response to the desired signal in the telephone receiver R is a maximum. When he has completed these adjustments, the time period of the open radiating circuit and the closed reservoir circuit are identical.

[fol. 257] Mr. Cosgrove: Plaintiff's counsel offers in evidence the drawing produced by the witness and requests that the same be marked "Plaintiff's Exhibit 93, type of radio apparatus manufactured by the Navy."

11. Question. What was the make or type of the detector T, indicated on the drawing, plaintiff's Exhibit No. 93?

Answer. Two types of detectors were present and adapted to be connected in circuit—one was the incandescent lamp detector, known as the audion, and the other was a crystal detector of common form. The former was manufactured by the De Forest Radio Telegraph & Telephone Co., and the latter by the Wireless Specialty Apparatus Co.

12. Question. Was the incandescent lamp detector referred to in your last answer known as the De Forest audion?

Answer. Yes; it was.

13. Question. Please look at the article now handed to you and state if you know what it is?

Answer. This article is a crystal detector manufactured by the Wireless Specialty Apparatus Co., and known as the silicon detector. It is a type which is in common use.

Mr. Cosgrove: Plaintiff's counsel offers in evidence the detector identified by the witness and requests that the same be marked "Plaintiff's Exhibit No. 94, Wireless Specialty Apparatus Co. silicon detector."

14. Question. Do you know or what is your information as to about when the Navy Department commenced the manufacture of the radio apparatus testified to by you and illustrated in the drawing, plaintiff's Exhibit No. 93?

Answer. I was first aware of this fact in 1912.

15. Question. Your attention is called to plaintiff's Exhibit 69, contract of January 31, 1914, between the Kilbourne & Clark Manufacturing Co. of Seattle, Wash., and the Navy Department, for 5-kw. radio sets for ship installation in accordance with specification 16-R-1, except as modified in the contract. Are you familiar with the type of radio apparatus referred to in this contract? And if so, please state when and where and under what circumstances you became familiar with this type of radio apparatus.

Answer. Yes; I am familiar with this type of apparatus, because I saw one set which was supplied under the contract referred to in your question on board the steamship *Achilles* of the Panama line and I had an opportunity to inspect it.

16. Question. Will you please state the circumstances under which you inspected the Kilbourne & Clark type of radio apparatus on board the steamship *Achilles;* stating where the steamship was located at the time you made the inspection and how long you knew that the ship belonged to the Panama line, giving the full name of the steamship company, if you know it?

Answer. At the time the *Achilles,* which was at her dock at Sparrows Point, Md., was about to make her trial trip, her builders the Maryland Steel Co. requested the Marconi [fol. 258] company to supply an operator to work the wireless equipment during this test and I went on board the ship with the operator. The name of the steamship company owning the ship, if I recollect, was the Panama Steamship Co., and I believe the name was painted on the ship.

17. Question. Do you know anything of the relations, if any, between the Panama Steamship Line and the United States Government?

Answer. It is my understanding that the United States Government owns the controlling interest in that company.

18. Question. What knowledge or information have you of the sale by the Kilbourne & Clark Co. of the type of radio apparatus installed on the steamship *Achilles?*

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Answer. Mr. Simpson, general manager of the Kilbourne-Clark Co. stated in my presence that this particular equipment was made *his* his company and sold to the Navy Department. It is my recollection also that the name plate on the apparatus, which I saw had the same contract number as that of the contract which you have handed me for inspection.

19. Question. Please briefly describe and explain the construction and arrangement of the Kilbourne & Clark type of apparatus installed on the *Achilles* and its mode of operation and such adjustments as would be made by an operator in the normal working of the set, producing and referring to any drawing you may have of the same.

* * * * * * *

Answer. The Kilbourne & Clark apparatus on board the steamship *Achilles* consisted of complete transmitting and receiving apparatus. I produce a diagram (P. Ex. No. 95) showing the circuit connections. The sketch marked "Transmitting station" shows the transmitter circuits and consists of an open radiating circuit, shown in black, and a closed oscillating or reservoir circuit, shown in red, together with a power supply circuit shown in yellow. The elements of the open radiating circuit are an antenna *f*, a connecting lead therefrom, A, and inductance *g*, with a variable contact 1, an inductance *d'* with a variable contact 2 and a connection to earth E. The closed circuit elements are a spark gap G, a condenser *c*, a variable inductance *d* and *d'*, having variable contacts 3 and 4. This closed oscillating or reservoir circuit was coupled inductively through the coil *d* to the coil *d'* in the open radiating circuit. The power transformer C and its high tension terminals connected to the spark gap G and its low tension terminals through an operator's key *b* to an alternating current generator *a*.

The method of operation of this transmitter is identical with the method of operation of the transmitter manufactured by the Navy Department which I have referred to. By opening and closing the key the operator interrupts the flow of current in the open radiating circuit, causing a series of dots and dashes, and therefore intelligible signals, to go out from the antenna *f*. The receiving apparatus of the Kilbourne & Clark type on board the *Achilles* consisted of an open radiating circuit, shown in the attached diagram [fol. 259] in black, a closed reservoir circuit shown in red

and an indicating circuit shown in green. The elements of the open radiating circuit are an antenna *f*, a connecting lead therefrom A, variable condenser *h*, which was adapted by means of a suitable switch to be connected in the position shown in dotted lines in the diagram or in the position shown thereon in solid lines, a variable inductance *d'*, contacts 5 and 6, a variable inductance *j'*, a connection to earth E, the closed oscillating or reservoir circuit comprised the inductance coil j^2, with its variable contact 7, the variable condenser *h'*, the stopping condenser j'^3, and the detector T. This circuit was coupled to the open radiating circuit through the coils j^2 and *j'*. Attached to the terminals of the blocking condenser is a telephone receiver R, which is connected through a variable contact 8 to a potentiometer *y*, to which is connected a battery B. The method of adjusting and using this receiving apparatus is identical with the method of using and adjusting the apparatus manufactured by the Navy Department, which I have described above.

20. Question. What can you say as to the tuning of the transmitting station and the tuning of the receiving station of this Kilbourne & Clark type of apparatus and means for accomplishing this?

Answer. This transmitter of the Kilbourne & Clark apparatus could be tuned, in so far as the open radiating circuit is concerned, by varying the amount of the inductance coil *g* and the inductance *d'*, included in the circuit by the variable contacts 1 and 2. The closed oscillating transmitter of the circuit could be tuned by adjusting the amount of the inductance *d*, *d'*, included in the circuit by means of the variable contacts 4 and 3.

The receiving apparatus could be tuned in so far as the open radiating circuit is concerned by adjusting the variable condenser *h* and the variable inductances *g'* and *j'* by means of their variable contacts 5 and 6. The closed circuit could be tuned by adjusting the inductance j^2 by means of its variable contact 7 and the variable condenser *h'*.

Mr. Cosgrove. Plaintiff's counsel offers in evidence the drawing produced by the witness in answer to Q. — and requests that the same be marked "Plaintiff's Exhibit No. 95, drawing, Kilbourne & Clark type of radio apparatus."

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21. Question. One of the previous witnesses has referred to radio apparatus used by the Navy, manufactured by Fritz

Lowenstein. What, if any, opportunity have you had to become familiar with the construction and mode of operation of radio receivers of the type made by Fritz Lowenstein for the United States Navy Department?

Answer. I saw some of these receivers in process of manufacture in the works of the Electrical Industries Co., New York City.

22. Question. Please state about when you saw the Lowestein type of receivers in the process of manufacture, as referred to in your last answer, and how you knew they were being made for the United States Navy.

Answer. I saw these receivers some time in 1912 and was informed by the maker that they were Lowenstein receivers and were intended for use by the Navy Department.

* * * * * * *

[fol. 260] 23. Question. Did you inspect and understand the construction and the intended mode of operation of the Lowenstein type of receivers referred to in your previous answers?

* * * * * * *

Answer. Yes; I did.

24. Question. Briefly describe or state what the construction and intended mode of operation was of these Lowenstein type of receivers, producing and referring to any drawing or diagram you may have thereof.

Answer. I produce a diagram (P. Ex. No. 96) entitled "Lowenstein type of receivers." This receiver comprised an open circuit, shown in black line, a closed oscillating circuit, shown in red lines, and an indicating instrument circuit, shown in green lines. The open circuit comprised the antenna f, the inductance g', the inductance j', the variable contacts 1 and 4, and the variable condenser h and the connection to earth E. The closed oscillating circuit comprised inductance j^2, having a variable contact 2 and inductance j^4, having a variable contact 3, a condenser h', a detector T, and a stopping condenser j^3. Connect-d across the detector T was a telephone receiver R. This closed circuit was coupled to the open circuit through the coils j^2 and j', and could be tuned to a desired period by the adjustment of either of the inductances j^2 or j^4, or the variable condenser h', or both. The open circuit could be tuned to a desired period by vary-

ing the variable inductances g' and j', or the variable condenser h, or both. The method of operating this receiver was identical with the method of operating the Navy receiver previously described.

25. Question. I call your attention to plaintiff's Exhibit No. 57, contract of April 22, 1911, between Fritz Lowenstein and the Navy Department, and particularly to the description and illustration of the receivers called for by that contract, the particular illustration being marked "Appendix III—Alternative receiver, proposal 1," and marked "R-R-8." How did the Lowenstein type of receivers you have testified to and which are illustrated in the drawing thereof and produced by you compare with the Lowenstein alternative receiver No. 1 of the contract referred to?

Answer. The two are substantially the same, and the diagram which I have produced is a simplified diagram which is electrically identical with that shown in Exhibit No. 57, drawing R-8.

26. Question. Do you recollect what the type of detector which formed part of the Lowenstein receivers you have referred to was?

Answer. The detector was of the crystal type.

27. Question. What was the type of detector forming part of the set of the Kilbourne and Clark apparatus installed on board the *Achilles?*

Answer. It was a crystal detector very similar in general construction to the crystal of Exhibit No. 94 and was manufactured by the same company, namely, the Wireless Specialty Apparatus Co.

Mr. Cosgrove. Plaintiff's counsel offers in evidence the drawing produced by the witness and requests that the same be marked "Plaintiff's Exhibit No. 96, drawing, Lowenstein type of receiver."

[fol. 261] 28. Question. Are you familiar with and do you understand the construction and mode of operation or intended mode of operation of the radio apparatus manufactured by the U. S. Signal Corps, referred to in your answer to question 4, and which you were asked by the Signal Corps to consider the matter of duplicating?

Answer. Yes; I am familiar with the pack set made by the Signal Corps, more particularly with the same equip-

ment made for the Signal Corps by the National Electric Supply Co. of Washington. I saw one of these sets exhibited by the Signal Corps at an electrical show in the Grand Central Palace about two years ago, as I remember it.

29. Question. Do you know about when the Signal Corps commenced to manufacture the radio pack sets referred to in your last answer?

* * * * * * *

Answer. No; I do not know, except that in a general way I have known for the last couple of years, I should say, that they manufactured these sets themselves.

30. Question. How did the radio pack sets manufactured by the United States Signal Corps that you referred to compare in construction and mode of operation with the radio sets manufactured by the Navy, concerning which you have testified to and which are diagrammatically illustrated in plaintiff's Exhibit No. 93?

* * * * * * *

Answer. Electrically, the sets are substantially identical, as is also their mode of operation. Mechanically, of course, they differ quite widely.

31. Question. How do you know the pack set referred to in your answer to Q. 28 as being made for the Signal Corps by the National Electric Supply Co., of Washington, and which you saw exhibited by the Signal Corps at the electrical show at the Grand Central Palace, was made for the United States Signal Corps by the National Electric Supply Co.?

Answer. As I recollect it, there were name plates on the apparatus, stating the manufacturer's name and, I think, also the fact that the apparatus was made for the Signal Corps. The sign in the immediate vicinity of the apparatus indicated that it was being exhibited by the Signal Corps.

32. Question. Did you make an examination or inspection of these radio sets made by the National Electric Supply Co. for the United States Signal Corps?

Answer. Yes; I did.

33. Question. What in general did these sets consist of?

Answer. They consisted of a complete transmitting and receiving equipment, except the aerial, and both the transmitter and receiver had two tuned circuits each.

34. Question. I call your attention to plaintiff's Exhibit No. 51, contract dated January 23, 1914, between the National Electric Supply Co. and the Signal Corps of the United States Army, and particularly to the drawing annexed thereto, No. 988, and marked "Field radio pack set, model 1914"; also to plaintiff's Exhibit No. 90, Radio [fol. 262] Telegraphy, 1914, and the drawing on page 109 thereof. Please state how the radio apparatus referred to in said contract and illustrated in the two drawings referred to compare in construction and mode of operation with the National Electric Supply Co.'s field pack sets made for the U. S. Signal Corps, which you saw and inspected at the Grand Central Palace.

Answer. These are identical in all respects.

35. Question. Was the radio apparatus manufactured by the Navy, concerning which you have testified, and which is shown diagrammatically in plaintiff's Exhibit No. 93, operated in your presence when you inspected it at the Grand Central Palace in the city of New York?

Answer. The receiving apparatus was, but I do not recollect clearly whether or not the transmitting apparatus was.

36. Question. What was the type of detector forming part of the pack set of the National Electric Supply Co. made for the United States Signal Corps which you saw exhibited at the Grand Central Palace?

Answer. A crystal detector.

Cross-examination.

By Mr. Workman:

The witness was then cross-examined by the counsel for the defendant, and in answer to interrogatories testified as follows:

37. Cross-question. When and where was your first experience with practical wireless telegraphy?

Answer. 1908, at Brant Rock, with Professor Fessenden.

38. Cross-question. Was this at the time you were employed by the National Electric Signaling Co.?

Answer. Yes.

39. Cross-question. And from service with that company you went to the plaintiff, Marconi Wireless Telegraph Co., did you?

Answer. Yes.

40. Cross-question. It was no new service or employ-

ment when you went with the Marconi company, was it; the Marconi company took over the National Electric Signaling Co. and continued your employment?

Answer. It was new employment, and the National Electric Signaling Co. was not taken over by the Marconi company, but still exists as a separate concern.

41. Cross-question. Was there any interim between your employment by the National Electric Co. and the Marconi company?

Answer. Yes; about a month.

42. Cross-question. Your work with the Westinghouse company had nothing to do with wireless telegraphy, had it?

Answer. Not directly; no.

43. Cross-question. And your employment with the De-Laval Turbine Co. was of mechanical and not of an electrical nature, was it not?

Answer. It was more mechanical than electrical, but consisted of both.

44. Cross-question. The electrical part of it had nothing to do with wireless telegraphy I suppose, did it?

[fol. 263] Answer. With one exception, no; the exception being that I did some work on a high-frequency alternator which the DeLaval company was building for the National Electric Signaling Co.

45. Cross-question. In what other suits for patent infringements relating to wireless installations or apparatus have you testified?

Answer. Marconi *v.* National Electric Signaling Co.; National Electric Signaling Co. *v.* Marconi; Marconi *v.* Radio Telegraph & Telephone Co. and Lee DeForest; Marconi *v.* Kilbourne & Clark Manufacturing Co. Those are all I recollect at this time.

46. Cross-question. The suit in which you testified, of Marconi against the National Electric Signaling Co., was in the matter of the so-called four-circuit tuning patent, was it?

Answer. Yes; that patent was involved.

47. Cross-question. And it was also involved in the Kilbourne & Clark suit, was it not, in which you testified?

Answer. Yes.

48. Cross-question. Was it not the so-called Lodge or loading-coil patent also involved in the Kilbourne & Clark suit in which you testified?

Answer. Yes.

49. Cross-question. And the Fleming patent for the so-called valve detector was involved in one of these suits you have mentioned, was it not?

Answer. Yes.

50. Cross-question. Which of the suits was the Fleming valve patent involved in?

Answer. Marconi *v.* DeForest Radio Telegraph & Telephone Co.

51. Cross-question. In the suits with the National Electric Signaling Co. which party called you as witness in those two instances?

Answer. The Marconi company.

52. Cross-question. You referred to having done a great deal in offering to supply the Government with radio apparatus and submitting a large number of bids. Were any of these bids accepted?

Answer. Yes; quite a number of them.

53. Cross-question. Were such bids for Marconi apparatus?

Answer. They were for apparatus manufactured by the Marconi company, in accordance with the specifications and requirements of the various Government departments.

54. Cross-question. Did you make this drawing produced in your direct testimony, marked "Plaintiff's Exhibit No. 93, type manufactured by the Navy"?

Answer. No. It was made by a draftsman from information which I supplied to Mr. Peters, I think, and it was approved by me after it was made.

[fol. 264] 55. Cross-question. The Mr. Peters you have referred to is associated with the firm of Sheffield & Betts, counsel for the plaintiff herein?

Answer. Yes.

56. Cross-question. When was it you supplied the information for this drawing?

Answer. I don't just remember, but some months ago.

57. Cross-question. It was on just a casual visit to the electrical show at the Grand Central Palace that you happened to see the wireless apparatus which you stated was exhibited by the Navy Department and which I understand you also to say that this plaintiff's Exhibit No. 93 is a schematic drawing?

Answer. Yes.

58. Cross-question. Do you recall how much time you spent examining the apparatus referred to?

Answer. An hour perhaps.

59. Cross-question. Who was in charge of the exhibit, if you know, at the time you saw it?

Answer. I don't know.

60. Cross-question. Did you talk with anyone in charge of the exhibit on this occasion?

Answer. Yes; I think I did.

61. Cross-question. The apparatus was explained and described to you by some one in charge?

Answer. Well, I think the questions which I asked were answered.

62. Cross-question. Then you actually saw all the apparatus, that you have indicated in this drawing you have produced of the apparatus, exhibited on that occasion?

Answer. The major portion of it; yes.

63. Cross-question. You actually saw the antenna *f* in that exhibit?

Answer. Yes.

64. Cross-question. Is the same feature that you have referred to in your answer at the aerial?

Answer. Yes.

65. Cross-question. It isn't usual, is it, to have the antenna or aerial in a room?

Answer. No; quite unusual, but this particular aerial was supported outside on the building and I saw it from the street.

66. Cross-question. You didn't trace its connections with the particular apparatus in the exhibit room, did you?

Answer. Yes; I did, as the connections were open and easily seen.

67. Cross-question. You mean you could plainly trace the electrical circuit in an aerial which had to be outside of the building, do you, with the particular instruments of this exhibit?

Answer. Yes; because a part of the aerial and its connection to the instrument could be seen through a window, through which or near which the antenna connections came from the outside to the inside.

68. Cross-question. And you actually saw, did you, the alternating current generator *a* which you have so marked in this exhibit drawing?

Answer. Yes; I think I did.

[fol. 265] 69. Cross-question. The exhibit drawing No. 93 would indicate that there were two separate aerials *f*, one

for receiving and one for transmitting. Is this what you actually saw.

Answer. The sketch does not purport to indicate the mechanical construction—but merely electrical circuits. In so far as the electrical circuit is concerned, the drawing shows what I saw. There was, of course, only one actual aerial structure, which was connected as desired to either the transmitter or the receiver.

70. Cross-question. There is nothing on this Exhibit 93 drawing to show this interchangeable connection of the single aerial, is there?

Answer. No.

71. Cross-question. In speaking of the left-hand circuit, marked "Transmitting station," you have mentioned the parts antenna *f*, connecting lead therefrom marked A, variable inductance or loading coil marked *g*, having the variable contacts marked 1 and 1ª, second inductance *d'*, having variable contacts, such as 3, which you say "constituted the primary of the oscillation transformer." Is that correct or doesn't this circuit constitute the secondary of the oscillation transformer?

Answer. The inductance *d'* does constitute the secondary of the oscillation transformer and I really think that is what I said, although the transcript reads "primary."

72. Cross-question. Would the fact that there was actually only a single aerial or antenna in the set which you saw instead of two, as the drawing represents, have anything to do with your calling the circuit last referred to the primary?

Answer. Nothing whatever. If I did call it the primary, it was merely a slip in words.

73. Cross-question. On the receiving side of this drawing, Exhibit No. 93, the circuit aerial *f*, antenna A, condenser *h*, inductance *j'*, and earth E, that is in fact, is it not, the primary of the oscillation transformer?

Answer. It is the primary of the oscillation transformer circuit—the coil *j'* alone is called the primary of the oscillation transformer.

74. Cross-question. In the actual apparatus that you saw on the occasion referred to, were there two separate and distinct and different coils *d'* and *j'*, or was there only one such coil, similarly as in the case of the antenna *f*?

Answer. These were two separate and distinct coils.

75. Cross-question. As a matter of fact, isn't it true that on looking at an exhibit of wireless apparatus that all you see is a set of instruments, such as a coil or coils, some switch handles, a button, and the like, and you don't see the actual run of the circuits or connections at all any more than you do when looking at a telephone instrument or the front of a switchboard?

Answer. No; that is not the fact. Actually in an average wireless outfit, particularly the transmitter, you could see every part of a circuit complete from one end to the other.

76. Cross-question. Do you mean to say you can see all this without removing or displacing the exhibit or parts of the exhibit?

Answer. Yes; so far as the transmitter is concerned, in the particular sets referred to everything was open, except the power transformer, and in this the usual terminals were visible.

[fol. 266] 77. Cross-question. By the power transformer, do you mean the coils represented as *d*, *d′* on the exhibit drawing 93?

Answer. No; I mean the power transformer C in yellow lines.

78. Cross-question. What was the actual physical character of the condenser *e* on this exhibit drawing No. 93?

Answer. It consisted of a number of glass jars, with metallic coating inside and outside, commonly called Leyden jars.

79. Cross-question. And were the condensers *h*, *h′*, and j^3 on the receiving side of the drawing of this same character?

Answer: No; they were not.

80. Cross-question. Were these condensers last mentioned all alike in physical character?

Answer. *h* and *h′* were alike—j^3 was of different physical character.

81. Cross-question. How did you know that they were condensers at all?

Answer. Partly from the markings on the instrument—partly from my general knowledge of this receiver—and as I recollect it the panel was stamped "primary condenser," indicating *h*, and "secondary condenser," indicating *h′*.

82. Cross-question. All these last three objects that you have called condensers were mounted on the same base or panel, were they?

Answer. The condensers h and h' were—the condenser j^3 was mounted externally, I think, on a different support.

83. Cross-question. And you mean to say, do you, that the wire or circuits leads to and from these various features of the apparatus were not concealed underneath or at the back or base of the panel on which they were mounted, after the fashion of the back of the base of this crystal detector, Exhibit No. 94?

Answer. No; I do not mean to say so—most of the connecting leads of the receiver were visible only at their terminals.

84. Cross-question. I note you have referred to the coil g in this exhibit drawing 93 as a "loading" coil. What was your reason for connecting that term to that particular coil?

Answer. Simply that it is the conventional name for it, and a name that is commonly employed by people in wireless work.

85. Cross-question. Why isn't the coil d' a loading coil, or why wouldn't it be correct to call this also a loading coil?

Answer. I expect it would be correct, but it isn't used, as that coil is commonly called the secondary of the oscillation transformer.

86. Cross-question. This exhibit of wireless apparatus which you say was made by the Navy Department, purported to be represented in the exhibit drawing 93, was not operated when you saw it on that occasion, was it?

Answer. The receiver was—I am not quite sure of the transmitter.

87. Cross-question. But you said there were two types of detector there. They were not both connected in the circuit, were they?

Answer. I said in my direct that they were so arranged that either could be connected as well.

88. Cross-question. Why did you refer to the condenser j^3, in this exhibit drawing, as a "blocking condenser"?

Answer. Because that is the conventional term employed by everyone in wireless.

[fol. 267] 89. Cross-question. Has it any connection with its function or mode of operation?

Answer. Yes; it has, when a battery is used with the detector as in the drawing marked "Kilbourne & Clark type," Exhibit 95. It prevents the direct current from the battery

from being short-circuited instead of going through the detector.

90. Cross-question. In connection with the Kilbourne & Clark type of apparatus just referred to exhibit drawing 95, you have referred to condensers j^3 as the "stopping" condenser. Does this term indicate the same character of condenser, its operation or function as the term "blocking" condenser?

Answer. Yes—the two words have the same meaning, when used with respect to this condenser.

91. Cross-question. Referring to the exhibit illustrated in exhibit drawing 93, Navy type, the arrangements for connecting either the crystal form of detector or the audion form, did not affect the connection of the blocking condenser j^3, did it, in the circuit?

Answer. That I am not sure of. It might leave it in the same position when either type of detector is used or it might remove it when the audion is used.

92. Cross-question. What I want to know is not what might be done, but what was the fact when you saw this exhibit, as to this. As I understand you, the various circuits and connections were all the time plainly apparent to you.

Answer. As I have already stated, I did not particularly notice the details of the transfer arrangements, as they were of no particular interest to me.

93. Cross-question. In the apparatus you saw exhibited at the Grand Central Palace, represented in the exhibit drawing No. 93, I understand you think you saw the alternating current generator *a*. Where was this with reference to the other parts of the apparatus?

Answer. I don't remember exactly, except in a general way that it was some little distance from the rest of the apparatus.

94. Cross-question. You didn't see any transmitting done from this apparatus, did you?

Answer. Well, as I said before, I think I did, but I am not quite sure.

95. Cross-question. But you did see receiving done. Is that correct?

Answer. Yes.

96. Cross-question. And you don't know whether this was done with the audion in circuit or with the crystal detector in circuit?

Answer. The audion certainly was used and I am fairly sure that the crystal also was used when I saw it working.

97. Cross-question. You didn't receive anything by using the apparatus yourself, did you?

Answer. I heard some of the signals, although I didn't actually copy any messages.

98. Cross-question. Those in charge allowed you to put the telephone to your ears, did they?

Answer. No; the signals were very loud, and one of the men with the apparatus held the telephone receivers near where I was standing.

[fol. 268] 99. Cross-question. That isn't at all the usual way of hearing wireless signals, is it?

Answer. It is a very common way if the signals are very strong; if the signals are weak, then it is necessary to put the telephone receiver closely against the ear.

100. Cross-question. In your description of the operation of this device in answer to Q. 10, you don't mean to say, do you, that you witnessed all these several adjustments being made as you have stated them, do you?

Answer. So far as the receiver is concerned, yes; so far as the transmitter is concerned, probably not; but my recollection is not very clear as to whether or not the transmitter was operated while I was there.

101. Cross-question. As a matter of fact, what you have described regarding the operation is no more than the stereotyped method of operation of almost any wireless installation, isn't it?

Answer. I have described what I know as the result of some considerable experience to be the method of operation of the particular apparatus referred to, and so far as the receiver is concerned, the actual method of operation which I saw.

102. Cross-question. Anyone desiring to operate any wireless transmitting installations will adjust his oscillating circuit until he gets the desired wave length, won't he?

Answer. Yes.

103. Cross-question. And he will adjust his antenna circuit to correspond, won't he?

Answer. Yes; I think he will, if he intends to get the best results.

104. Cross-question. And the inductance coils or the coupling coils are the things usually adjusted to get this effect, are they not?

Answer. Yes.

105. Cross-question. And if you are operating any receiving installation any intelligent operator will adjust his condensers and inductances until the response to the signal he is receiving is a maximum, won't he?

Aswer. Yes; generally, although there are exceptions, such as, for instance, when he wishes to receive one station to the exclusion of some other interfering station, in which case to get maximum freedom from interference he may not adjust for maximum signal strength, but rather for the sharpest possible tuning.

106. Cross-question. Well, doesn't sharpest possible tuning mean the same thing as maximum response to the signal to be received?

Answer. Not necessarily; no.

107. Cross-question. At any rate, even in that case, the adjustments are made until the best response is secured to the signal desired to be received. That is correct, isn't it, whether this may be the sharpest tuning or not?

Answer. In a general way; yes.

108. Cross-question. Isn't it a fact that in receiving wireless signals the receiving circuit has to be so adjusted as to be in resonance to the incoming signals?

Answer. Yes; most certainly, for best results.

109. Cross-question. And the only way of securing such resonance is by adjusting the condensers or the inductances or both. That is correct isn't it?

[fol. 269] Answer. It is correct, in so far as it refers to a receiver designed to work at a considerable number of wave lengths. A receiver easily can and often is made without adjustments; that is, it is built with fixed condensers and inductances and intended to operate at one wave length only; that is to say, it is as manufactured already in tune for some particular wave length.

110. Cross-question. Any resonant circuit, in order to be such, has to have in it capacity and inductance. That is correct, is it not?

Answer. Yes.

*   *   *   *   *   *   *

111. Cross-question. On what do you base your statement that you were aware of the fact that the Navy Department commenced to manufacture radio apparatus corresponding to that illustrated in the exhibit drawing No. 93 in 1912?

Answer. I don't think I put it just that way. I said that I was first aware of the fact that they were making apparatus of this kind in 1912—that is to say, my personal knowledge commenced with that date—and I do not mean that they commenced to manufacture at that date, because I do not know when they commenced making their own apparatus.

112. Cross-question. Do you recollect when it was you saw the Kilbourne & Clark type of radio apparatus on the S. S. *Achilles?*

Answer. About Decoration Day 1915.

113. Cross-question. I suppose you were not the operator referred to in your answer to question 16 that the Marconi company was requested to supply for this equipment?

Answer. No; I was not.

114. Cross-question. Was such operator actually supplied by the Marconi company?

Answer. Yes.

115. Cross-question. What was your connection with that equipment?

Answer. Well, I inspected it and gave the operator some instructions in the matter of handling it.

116. Cross-question. Is it usual for the Marconi company to supply operators for wireless equipment that are not of their own make?

Answer. I think so; yes; although it is not a particularly frequent occurrence.

117. Cross-question. Why did you employ the term "reservoir circuit" to the circuit shown in red on the left or transmitting side of drawing, Exhibit 95, Kilbourne & Clark type?

Answer. It is a conventional term and has a real physical meaning, as indicating the circuit in which energy is stored to be later dissipated in the radiation from the open radiating circuit.

118. Cross-question. What was the reason you didn't employ this term with reference to the corresponding red circuit in exhibit drawing 93, type manufactured by Navy?

Answer. No particular reason that I know of—the same term applies equally there, and I could have used it with equal appropriateness.

[fol. 270] **119. Cross-question. And this term would be equally appropriate to any closed oscillation circuit that was connected to transfer its energy to a radiating circuit?**

* * * * * * *

Answer. **As to that I couldn't say in a general way—it might or might not be appropriate, depending on the conditions of a specific case.**

120. Cross-question. **When did you make this exhibit drawing 95, Kilbourne & Clark type?**

Answer. **That I don't remember exactly; it was quite a while ago.**

121. Cross-question. **As long ago as Decoration Day 1915?**

Answer. **I may have made a sketch essentially the same as this drawing about that time.**

122. Cross-question. **You haven't any present recollection that you did make such sketch about that time?**

Answer. **Well, I know that within a comparatively short time after that I made sketches showing the circuits of this transmitter and receiver.**

123. Cross-question. **Can you produce those sketches now?**

Answer: **No; I don't think I can.**

124. Cross-question. **You didn't actually make this exhibit drawing 95 yourself, did you?**

Answer. **It was made from information which I supplied and checked by me, but a draftsman did the actual work of making the lines.**

125. Cross-question. **As you are not able to produce original sketches made at or shortly after the time you saw this installation, I suppose those sketches were not the ones or the information that you gave the draftsman for this Exhibit No. 95, were they?**

Answer. **As to that I don't remember.**

126. Cross-question. **Do you mean to say that you don't remember that the sketches or whatever it was you furnished the draftsman for making exhibit drawing 95 were the ones you made shortly after the time you saw this apparatus?**

Answer. **No; I don't remember definitely.**

127. Cross-question. **What's the reason the condenser *h* on this Exhibit No. 95 is shown in dotted lines?**

Answer. To indicate that this particular connection is alternative to the connection of condenser *h*, indicated by the solid line.

128. Cross-question. You didn't see this apparatus operated, did you?

Answer. No; I did not.

129. Cross-question. When you saw it was it installed for operation?

Answer. Yes.

130. Cross-question. You didn't mention what the character of the detector T was in this Kilbourne & Clark receiver?

Answer. It was a crystal detector, identical in form with the detector of plaintiff's Exhibit No. 94.

131. Cross-question. Referring to drawing No. 93, type manufactured by the Navy, I observe that there does not [fol. 271] appear to be any potentiometer in the green circuit as there is in exhibit drawing 95. Is this an omission in the former drawing?

Answer. No; it is common practice to use crystal detectors either with or without a potentiometer.

132. Cross-question. And there appears to be no battery in exhibit drawing No. 93, as there is in exhibit drawing No. 95 in the green circuit or for that matter in the receiving circuit at all. Is that an omission in drawing No. 93?

Answer. No; the battery and potentiometer go together and when it is not used the other is not used with the crystal detector.

133. Cross-question. And as to this Exhibit No. 95, do you mean to have it understood that it had two antennæ or aerials *f*, as indicated on the drawing—one for transmitting and one for receiving?

Answer. No; one antenna only and a switch for connecting either to transmitter or receiver as well.

134. Cross-question. Who installed this Kilbourne & Clark apparatus on the *Achilles*, if you know—the Marconi company or the Kilbourne & Clark people?

Answer. I am not sure, but I don't think either company did.

135. Cross-question. As a matter of fact, all you saw of this installation were the instruments mounted on the panels or baseboards, was it not?

Answer. No. I saw practically every detail of this set, including the inside of the receiver and the various con-

necting wires, switches, etc., and also a complete wiring diagram and instructions supplied by the maker of the apparatus with it.

136. Cross-question. On examining the drawing marked "Appendix 3—Alternative receiver, proposal No. 1," part of Exhibit No. 57, I fail to observe the coil corresponding to the coil you have marked on the diagram you have produced Exhibit No. 97, Lowenstein type of receiver, corresponding to g' on that diagram.

Answer. Referring to the Exhibit 57 which you have referred to the two coils shown at right angles and marked "Primary variometer" correspond to the coil g' of the Exhibit No. 97.

137. Cross-question. Is it your understanding that the coils marked II, III, and IV are in the closed oscillation circuit, referring to Appendix 3, R-8 drawing, part of Exhibit No. 57?

Answer. Coils II, III, and IV are in the closed oscillating circuit.

138. Cross-question. Referring to the pack sets stated by you to be made by the Signal Corps that you say you saw at an electrical show about two years ago, in what condition were these sets when you saw them—packed up for transportation?

Answer. No. They were in practically complete condition for operation, except that I don't recollect any connection to the antenna.

Redirect examination.

By Mr. Cosgrove:

139. Redirect question. Referring to Plaintiff's Exhibit No. 94, Wireless Specialty silicon detector, do you know whether that type of detector has been used by the Navy since 1910?

Answer. Yes; I know that has been the standard form of detectors with them since that time.

140. Redirect question. In your answer to X Q. 53, you referred to apparatus being manufactured by the Marconi company under specifications and special requirements of [fol. 272] the Government departments. Did those specifications include plaintiff's Exhibits Nos. 37, 38, 39, and

40, Navy wireless specifications to which your attention is now directed?

* * * * * * *

Answer. Yes.

141. Redirect question. How did the Marconi apparatus supplied to the Government under these specifications or any of them compare electrically and in mode of operation with that manufactured by the Navy and concerning which you have testified to?

* * * * * * *

Answer. They were substantially identical.

142. Redirect question. Was the Kilbourne & Clark apparatus, which you inspected on the S. S. *Achilles* new?

Answer. Apparently so; yes.

The examination of counsel being concluded, the witness, in compliance with the rule of the court requiring him to state whether he knows of any other matter relative to the claim in question, and if he does to state it, says he does not.

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[fol. 273] "By Mr. Cosgrove: Claimant's Counsel offers in evidence the following:

"Pamphlet entitled 'Radiotelegraphy' U. S. Signal Corps, revised 1916, forming part of the said report of the War Department filed on May 16, 1917, and requests that the same be marked *Plaintiff's Exhibit 'Radiotelegraphy, 1916.'*

"Also drawings marked No. '642-1, U. S. Signal Corps January 1908, as revised and drawing 741-1, U. S. Signal Corps November 23, 1908,' forming part of the said report of the War Department, and requests that the same be marked Plaintiff's Exhibits No. 97 and No. 98, *Signal Corps Drawings, Field Wireless Pack Set.*"

Deposition of Frank N. Waterman, for claimant, taken at New York, N. Y., on the 24th day of August, A. D. 1917, and subsequent dates.

Frank N. Waterman, deposed and said that his name is Frank N. Waterman; that his occupation is that of consulting engineer; that he is 51 years of age; that his place of residence is Summit, N. J.; and that he is not interested

in the claim in question and that he is not related to the claimant.

Direct examination.

By Mr. Cosgrove:

1. Question. Please state what theoretical and practical experience you have had in electrical matters, particularly with the subject of wireless telegraphy, which would tend to qualify you as an expert in such matters?

Answer. I graduated from the course in electrical engineering at Cornell University in 1899. Prior to my graduation I had had practical electrical engineering experience in the employ of the Waterhouse Electric & Manu-[fol. 274] facturing Co., and upon my graduation I entered the employ of the Westinghouse Electric Co. and was with that company in various capacities until the fall of the year 1900. During this connection with the Westinghouse company I was engaged in the development of alternating current motors, of arc lighting apparatus, electric railway apparatus, also in the installation of electrical plants of various sorts. I was afterwards engineer of the New York office and subsequently engineer to the legal department.
[fol. 275] Since 1900 I have been engaged in the profession of consulting engineer, and during this period have frequently testified in litigations involving electrical matters and apparatus.

For many years I have been engaged in the study and investigation of the subject of wireless telegraphy and have for at least five or six years owned and operated for experimental purposes a complete wireless telegraph station and a laboratory suited to the investigation of wireless telegraph problems.

I am a practical operator and have held, though I do not at the present time, a first-grade commercial operator's license. I also held a license to operate an experimental station granted by the United States Government up to the time when all licenses were revoked on account of the war. I have testified as an expert in a number of litigations involving wireless telegraphy and its appliances, and have conducted many investigations into the mode of operation of such appliances.

2. Question. Have you read the depositions of Messrs. Graham, Langley, and Weagant, taken on behalf of the

plaintiff herein, and examined the exhibits referred to by them or introduced in connection with their respective depositions, and do you understand the construction and mode of operation of the wireless telegraph apparatus and devices referred to in said depositions and said exhibits?

Answer. I have and do.

3. Question. Have you read and do you understand the Navy wireless specifications 16-T-5 and 16-R-1, marked "Plaintiff's Exhibits Nos. 37 and 38," and the Army wireless specifications Nos. 547 and 566, marked "Plaintiff's Exhibits 42 and 43"?

Answer. Yes.

4. Question. Have you read the patents here in suit, and do you understand the respective inventions thereof as described therein and illustrated in the drawings thereof, particularly as embodied in claim 3 of the Marconi reissue patent No. 11913; claims 1, 2, and 5 of the Lodge patent No. 609154; claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 16, 17, 18, 19, and 20 of the Marconi patent No. 763772; and claims 1 and 37 of the Fleming patent No. 803684?

Answer. I have read the patents and believe that I understand what is there disclosed and particularly as specified in the claims referred to in the question.

5. Question. Please look at the sheets of colored drawings now handed you and state, if you know, what such drawings represent.

Answer. I do. They illustrate in diagrammatic way, distinguishing different parts by the aid of colors, the apparatus as referred to in the Marconi reissue patent, the Lodge patent, and the Marconi later patent, all in suit.

Mr. Cosgrove. Plaintiff's counsel offers in evidence the three sheets of drawings just identified by the witness and requests that the same be marked "Plaintiff's Exhibit No. 99, Waterman diagrammatic drawings of Marconi and Lodge patents in suit."

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6. Question. In order that the court may understand the subject matter of the inventions of the claims in issue of the Marconi and Lodge patents in suit referred to in Q. 4, will [fol. 276] you please explain as briefly as you can the art to which those inventions relate and the way any devices or apparatus you may refer to function or operate, defining and explaining such technical or scientific ideas and terms

used in the art and in said patents, and making use of any exhibits already introduced herein and such drawings or sketches as you may find necessary to make in order to give a full and intelligent understanding of such subject matter?

Answer. The three patents inquired about relate to the transmission of intelligence by means of Hertzian waves and the apparatus concerned comprises, generally speaking, a transmitting station at which is located the apparatus for generating and radiating these waves, and a distant receiving station which receives and detects the transmitting waves and produces thereby some interpretable evidence of their passage, such as a printed tape or some audible or visible indication intelligible to the operator. In the earlier commercial types the message was received in the form of dots and dashes printed upon a tape, but in present-day practice the more rapid method of reading the signal by its sound is more customarily used, or a visual indicator can be employed if preferred.

Hertzian or electric waves.—These wireless waves, which are radiated from the transmitter, are of the same nature as light waves, and they are transmitted through the same medium which serves for the propagation of light waves, namely, the so-called universal ether, but they differ therefrom in being of greater wave length.

We have sense organs capable of receiving and detecting ether waves, having that range of wave length known as light. Shorter wave lengths are known to exist which are detectible by the photographic plate, such, for example, as the so-called ultra-violet light and X rays.

We also have sense organs for perceiving ether waves, somewhat longer than light waves, namely radiant heat. When, however, ether waves longer than radiant heat waves exist the human senses are unable to detect their presence, and the receiving wireless telegraph station comprises apparatus for effectively receiving, detecting, and rendering perceptible such transmitted waves.

A wireless telegraph transmitter is thus a sort of lighthouse, which emits light of an invisible nature, and just as it requires energy to produce light so power is consumed at the wireless telegraph transmitter to furnish the energy for the transmitted Hertzian or wireless-telegraph waves.

When light is sent out from the lighthouse and falls upon an object in its field, that object absorbs the energy coming to it, if it is not transparent, and thereby casts a shadow.

In similar manner objects which are not transparent to the Hertzian waves intercept these waves and cast a shadow, thereby absorbing the energy intercepted. It is thus the function of the receiving antenna to intercept the transmitted waves and absorb the minute amount of energy which reaches any particular spot where the receiver is located, and it is the function of the remainder of the receiving apparatus to turn to practical account the energy so received.

High-frequency oscillations and wave lengths.—The means employed to set up these wireless-telegraph waves radiated by the transmitter is an oscillating electrical [fol. 277] charge. If a stick of amber glass or hard rubber be rubbed, for instance, with a silk handkerchief, it will become electrified—that is, it acquires an electric charge—and the evidence of such a charge is seen in the fact that it will attract bits of paper or other light particles and is capable of imparting an electrical charge to other bodies.

There are two opposite sorts of electrical charges. Thus, when a stick of amber is rubbed, the bit of silk with which it was rubbed tends to stick to it, but if a portion of the charge acquired by the amber is imparted to some light object, that object which was at first attracted will be repelled. These two sorts of charges are commonly referred to as positive and negative charges, respectively.

I assume that everyone is now familiar with the elevated network of wire that indicates the presence of a wireless-telegraph station and which is seen stretched between the masts of ships or otherwise supported at an elevation, from which one or more wires lead downward into the operating room. These wires are of metal, and hence are good conductors of electricity. If we imagine a charge of electricity imparted to such an elevated conductor, it will, of course, immediately rush to the earth, because these elevated conductors are connected to the earth at their lower ends. In so doing the electrical charge will travel approximately at the speed of light—that is to say, about 186,000 miles per second. For reasons which I will not now stop to consider, this traveling charge moving at the high velocity of light will display the property of inertia and so will, so to speak, overtravel. Thus, if it was a positive charge that was imparted to the overhead wire, the rush of electricity to earth will not only reduce this charge to zero but a negative charge will take its place. The negative charge in turn will rush to earth and be succeeded by a positive charge, thus

completing a cycle of electrical charges in the elevated wire or antenna after the charge has four times traversed the length of the aerial or antenna wire. Since in one complete cycle or charge of the oscillatory charge the length of the antenna is traversed four times and then the same process is repeated, it is customary to refer to this as the wave length, and this wave length is therefore approximately four times the length of the antenna or elevated wire, and one may thus form a definite approximate conception of the order of magnitude of these wireless-telegraph waves.

From these facts we may also at once ascertain what is the speed or frequency of oscillation of the electrical charge and hence of the resulting electrical waves, for since the electrical charge and electrical waves both travel with the speed of light, it is evident that the number that would occur if the operation continued for one second would be equal to the speed of light divided by the wave length. If, for example, the wave length was one-tenth of a mile, then evidently the number of oscillations per second or the rate of oscillation would be 186,000 divided by one-tenth, or 1,860,000. In commercial practice the standard wave length is 600 meters, or a little short of 2,000 feet, and hence the frequency of oscillation is 500,000 per second.

Other frequencies are also in use, ranging from 1,500,000 per second, or a wave length of 200 meters, up to very long [fol. 278] wave lengths, such as a frequency of 30,000 per second, corresponding to a wave length of 10,000 meters, or something over 6 miles.

Difference of potential or voltage.—To understand how an oscillating electric charge causes an electrical wave to be produced and to form some idea of what an electric wave is it is necessary to have in mind what is going on in the space surrounding a moving charge. Whenever we have a positive electric charge we must also have a negative charge. For example, if we rub an amber rod with a silk handkerchief, one of these elements acquires a positive charge and the other acquires a negative charge. If these elements were conductors, a current would flow from one to the other when they were in contact. Between the two there exists an electrical pressure or difference of potential which is measurable in terms of a unit called a volt, and is evidence of a tendency for a current to flow. This electrical pressure is sometimes called the "voltage" of the circuit.

If we examine the condition of the space surrounding bodies between which there is a difference of potential, or, in other words, bodies that are charged, the condition of affairs indicated diagrammatically in Figure 1 of plaintiff's Exhibit No. 92, "Radiotelegraphy," issued by the Army, page 5, will be found to exist. * * * If two wires, one charged positive and the other negative, are passed upward through a sheet of paper and a very light-powdered nonconducting material be sprinkled upon the paper, the particles of powder will arrange themselves as shown by the curved lines of this figure, which originate in the wire marked with the plus sign and that marked with the minus sign. These curved lines denote lines of ether strain, this strain being caused by the presence of electric charges, or, in other words, by the difference of potential between the wires. It is a strain resulting from the electrical pressure upon the ether. If for example the difference of potential or "voltage" between the two be, say, 100 (as, for example, 100,000 volts), then along each one of these lines the pressure will diminish, so that a short distance from the positive wire on each one of these lines it will be 90, farther away it will be 80, and still farther 70, until when the negative wire is reached it will be zero. It will of course be understood that we might tip the paper at any angle with respect to the wires and we would still get similar lines extending from one to the other. In other words, the entire space surrounding a line connecting two points having a difference of potential has these lines in it. These lines are referred to as electrostatic lines of force, and the space so affected is referred to as an electrostatic field. Sometimes also the term "electrostatic field" is used as applying to the lines themselves.

Production of electric waves.—If we now imagine an elevated conductor as having a charge imparted to it so that with respect to the earth the elevated wire is positive while the earth is negative, then the electrostatic lines of force, which are brought into existence by the charge, will extend from the wire to the earth, as shown in Figure 3, on page 6, of Exhibit No. 92. * * * It will be noted that the particular arrangement of the lines of force is somewhat dif- [fol. 279] ferent from that of the preceding figure, because in this instance the vertical wire is positive, while the whole earth surrounding it is negative.

Remembering the illustrations given above, it will be seen that if the wire has a charge of 100 with reference to the earth taken as zero, then points in the surrounding space will have differences of potential with respect to the earth of 90, 80, 70, etc., as already explained.

If, now, a path to earth be provided for the charge stored in the wire, the charge will rush to earth with the speed of light. It is evident that as the charge moves there would be for each position a new system of electrostatic lines and that each point in the surrounding space will acquire a new difference of potential with respect to earth; that is to say, one which is different from that which it had a moment before. It is this rapid changing in the potential of the surrounding space which gives rise to the electric waves.

When the charge of electricity passes to earth electricity is moving from one point to another, and such a movement of electricity is called an electric current; it is measured in terms of a unit called the "ampere." When electricity so moves—that is, when a current flows—there is another set of ether strains produced. This is shown in Figure 4, on page 7, of the plaintiff's Exhibit No. 92 * * *. If the wire carrying the current were passed through a sheet of paper and iron filings were sprinkled upon the paper, the filings would assume a circular arrangement which is roughly indicated by a circle in this figure. It is interesting to note that the circles representing the electromagnetic field at any instant, as shown in this figure, connect points in space on the electrostatic lines of force which are of equal potential with respect to earth. The electrostatic lines and the electromagnetic lines are thus related to one another very much as are the lines representing longitude and those representing latitude on a globe.

The instant that the charge assumed to exist in the vertical wire begins to move earthward the electrostatic lines begin to disappear or collapse and the magnetic lines begin to appear and expand (thereby marking the exchange which is taking place in the electrostatic field). The sorts of strains then existing in the space around the wire are fragmentarily indicated in Figure 6, on page 8 of Exhibit No. 92 * * *. On this diagram lines such as S indicate electrostatic lines; those such as M indicate electromagnetic

lines. It will be understood that these constantly change in position as the charge moves, and when a negative charge is ascending the wire (immediately following the descending positive charge) then a similar cycle of events is passed through, as might be indicated by Figure 6, if all the arrow heads thereon were reversed in direction. (This is actually illustrated in Figure 7, page 9, of Exhibit No. 92.)

As the current passes down the wire in the above assumed case the ends of the electrostatic lines which originally terminated upon the wire ultimately are brought down to and terminate upon the surface of the earth. Since the collapsing of the field can not be entirely completed, it thus comes about that these electrostatic lines become entirely detached from the wire and are crowded off into space by the reversed motion of electricity in the wire, namely, [fol. 280] by the upward motion of the succeeding negative charge, so that a set of fluctuations of electrical potential exist in the space around the wire, and these are shot out into space with the velocity of light. They constitute rapid changes of electrical and magnetic conditions of the ether, moving outward just as the waves caused by dropping a stone into a still pool of water move outward from the spot where the stone fell. Every one has, of course, observed that long after the water where the stone was dropped has again become substantially quiescent the train of waves caused thereby is still traveling outward. This outwardly traveling motion of the water waves continues until the energy imparted to them by the falling stone has all been dissipated. In a similar manner the detached electrical waves just referred to travel outwardly, constituting an ever-enlarging set of circles, until their energy has been so reduced as to make them imperceptible. This energy never returns to the conductor.

It is clear that as the electrical charge oscillates up and down in the vertical wire, as just described, it is all the time parting with its energy in the form of electric waves (part of the energy is also lost as heat in the conductor). When the energy is exhausted so that the oscillation of the charge in the antenna ceases, then no further disturbance exists in the ether surrounding the wire but the "train of waves" set up by the oscillations continues to travel upward.

A fragmentary illustration of how such a train of waves may be thought of, as viewed in cross section, is shown in Figure 9, on page 11 of Exhibit No. 92. * * * In this figure the lines and arrows indicate partial cross sections of the traveling electrostatic fields as they might be at some particular instant, while the dots represent the cross sections of the electromagnetic lines. The phenomena occurring between an instant when the top of the wire is positive and the next time that the same point is positive are indicated by one double group of strain lines. In the figure herewith reproduced this distance is denoted by arrows marked "Wave lengths."

Wireless telegraph apparatus.—Passing now from the consideration of the sort of natural phenomena which are involved in wireless transmission, I will refer briefly to some of the apparatus employed and the principles upon which it is based.

The electric waves are radiated from and received by a vertical conducting structure, usually consisting of some considerable altitude, known as the antenna or aerial system, often called aerial for short. It commonly consists of an elevated structure, such as a network of wires, connected by a vertical wire or wires to the earth through appropriate intervening apparatus within the station. The particular form which the elevated network or "capacity aerial" takes is immaterial, although of course there will be specific or detailed differences of minor character following from different specific constructions.

Associated with the antenna at the transmitting station there is necessarily provided some suitable source of electrical energy. This may take the form of a primary battery or chemical generator of electricity or a secondary battery, wherein electricity previously generated has had its energy [fol. 281] stored by chemical change to be again given out when needed as a current of electricity. Such a battery is known as a storage battery.

For larger stations it is generally preferred to produce the electrical energy needed by means of a dynamo or mechanical generator of electricity driven by an engine, motor, or other source of power.

It is preferable and indeed essential that the antenna should be charged at a fairly high pressure, and hence it is necessary to have a means of furnishing this high

pressure. This usually takes the form of an induction coil (otherwise known as a Rhumkorff coil) or transformer.

Since these devices are not peculiar to wireless telegraphy but are used for other purposes as well, it will doubtless be sufficient to say that each consists of two coils of wire (or a single coil used for two circuits) associated upon an iron core, so that when a current flows in one coil it produces a magnetic field which affects the other coil. I have already pointed out that when a current flows a magnetic field, that is magnetic lines of force, are produced around the conductor. By suitably varying such a magnetic field it is possible to generate a current in an affected circuit. It thus becomes possible in an induction coil or transformer to generate a current of low pressure, safe and easy to handle, and by means of an induction coil or transformer produce another current of high potential suitable for charging the wireless telegraph transmitting antenna. In the case of the induction coil the necessary changes in the magnetic field are produced from a current of constant direction of flow by a mechanical current-interrupting device, known as an interrupter or vibrator, while in the case of the transformer the currents supplied to it are originally generated as currents alternating in direction.

When a current flows continuously in one direction, as is the case, for example, in the currents produced by a battery, the current is known as a direct current or continuous current, but when the current flows alternately in opposite directions in its circuit, because the terminals of the generator are caused to become alternately positive and negative, it is known as an alternating current. As employed in wireless telegraphy the number of alternations of the current produced by the generator has varied in commercial practice from 120 to 1,000 or more per second.

It is customary to regard a current flow first in one direction and then in the other as one complete cycle of change which is continuously repeated thereafter. Hence two such successive currents, i. e., a flow of electricity first in one direction succeeded by a flow in the opposite direction constitute one cycle, and it is customary to designate the current employed by the number of cycles as, for example, a current alternating 120 times per second is known as a 60-cycle current and one alternating 1,000

times per second is known as a 500-cycle current. The significance of the number of cycles, as will further appear, is merely that it determines how many charges are imparted to the antenna and radiated in any given period during which the operating key is held depressed by the operator.

In order to understand the patents in suit and the individual pieces of apparatus referred to therein it is necessary to understand some of the properties of an electric circuit, and I will, therefore, briefly outline these.

[fol. 282] *Properties of electric circuits.*—When a current flows in a wire it encounters an obstruction known as resistance. A fine wire will have a higher resistance than a coarse wire and a long wire a higher resistance than a short one. Some materials have higher resistance than others. For example, if we have silver, copper, aluminum, and iron wires of the same length and diameter, the silver wire will be the best conductor—that is, it will have the lowest resistance. Copper wire will be next, while the resistance of the aluminum and iron wires will be progressively higher, that of iron being the highest.

This property of resistance is thus characteristic of the material, and this resistance is experienced by both direct and alternating currents. It is measured in "ohms."

Inductance: An electric conductor has another property, and one which is of great importance in wireless telegraphy, which does not depend upon the material of the wire and not to any large extent upon its diameter, but depends substantially only upon the length of the wire and the way it is arranged. This property is known as the inductance of the wire, and it is analogous to inertia in mechanics.

For example, it is very difficult to suddenly start a heavy object in motion, but after such an object has acquired a considerable velocity it is very difficult indeed to quickly stop it.

Similarly the inductance of an electric circuit prevents a current from instantly rising to its full value in a circuit when an electrical pressure is applied, and it prevents the current from instantly stopping when the circuit is broken.

A straight wire has a certain amount of inductance, but this is small as compared to the inductance that the same wire would have if it were formed into a coil. It is thus possible to vary the inductance by varying the way in

which the wire is arranged. The unit of inductance is the "Henry."

A coil of wire arranged in the form of a coil, whether helical or spiral, in order that its property of inductance may be utilized in the circuit, is known as an induction coil. This must not be confused with the expression "inductance coil," as the term induction coil applies, as already defined, only to a structure designed to produce a high-tension current from a low-tension source of supply.

Capacity: Another property of an electric circuit, which is of great importance in wireless telegraphy, is that property by virtue of which it is possible to impart to it an electric charge. This property is known as "capacity." Capacity is measured in "farads" or "microfarads."

A structure built to display this property is known as a condenser.

If two plates of metal are placed one on each side of a piece of glass, the apparatus so constituted is a condenser, and a charge of electricity may be stored in it by connecting the two plates to the two terminals of a suitable source.

Another form of condenser which is familiar to most people consists of a jar or glass coated inside and out with tin foil or copper or silver plating.

All conductors possess capacity to a greater or less extent. For example, a coil of wire of itself possesses some capacity. A vertical wire or antenna possesses capacity, [fol. 283] and it is by virtue of this fact that it is possible to produce wireless waves at all. It is the capacity of the wire which enables it to be charged, and the amount of energy which can be imparted to the wire in such a charge is equal to the capacity of the antenna multiplied by one half the square of the charging pressure or voltage.

Capacity in a circuit is analogous to elasticity in mechanics, and hence when inductance and capacity are associated in a circuit the circuit has properties analogous to a mechanical apparatus having inertia and elasticity. It is by virtue of these properties that the current of the circuit is able to oscillate.

When energy is imparted to a capacity—that is, to a condenser—the energy is stored in the electrostatic field which is produced and which I have already described. When a current flows in a circuit, its energy is stored in the magnetic field produced by the flow of the current, and the

energy of this magnetic field is equal to the inductance of the circuit producing it multiplied by one-half the current flowing.

Losses due to resistance: When a current flows in a conductor and overcomes its resistance, heat is developed in the conductor and a certain amount of the energy is wasted in this heat. The amount of energy so consumed is equal to the resistance of the conductor multiplied by the square of the current. It is this heat development through the flow of the current which makes possible the incandescent lamp, the incandescent lamp being simply a device in which the energy is consumed in producing heat in order that light may result. In this case a certain amount of the energy is consumed in producing the light waves, but the greater part is expended in maintaining the temperature.

Properties of waves and oscillations: Since in dealing with the subject of wireless telegraphy we have to do with oscillatory motion in electric circuits and with waves in the ether, it is important to bear in mind the fundamental properties that are essential alike to waves and to free oscillatory motion. In order that a body or a circuit may oscillate or vibrate when energy is imparted to it, it must display the property of inertia, in order that it may acquire momentum, and it must also have elasticity or some equivalent restoring force. When a pendulum swings, it is the inertia of the bob which enables it to swing upward and it is the restoring force of gravitation which causes it thereafter to swing downward, and these two properties are essential to its motion. If I clamp a bit of spring wire by one end horizontally in a vise and attach a small weight to the end of it, it will vibrate or oscillate to and fro when once started by springing the end to one side. The reason it vibrates is because first the elasticity tends to restore the wire to its normal position and then the momentum of the weight carries it beyond that position, and this continues until the energy has been dissipated.

Similarly in order that there may be waves, whether in water or in air, or in the ether, there must be these two properties, inertia and elasticity. When the wind disturbs the surface of a body of water waves result, which continue for some time after the wind has ceased to blow. When a wave rises it is due to the momentum of the water and when it falls it is due to the action of gravitation tending

to restore the level. Such waves are gravital waves. [fol. 284] Everyone who has fished in still water has noticed that the motion of the line causes tiny ripples to spread outward. In this instance it is the elastic action or surface tension of the water which causes the ripples. Similarly sound waves in air are due to the fact that the air has inertia and also elasticity.

Similarly waves in the ether result from the fact that the ether displays the properties of inertia and of elasticity, and the free oscillation of energy in an electric circuit is due to the fact that the circuit possesses the properties of inductance and capacity corresponding to inertia and elasticity.

The length of time that will be occupied by one oscillation of a mechanical body or an electric circuit depends upon the magnitude of the inertia and elasticity and hence upon their product. The time period of oscillation of a circuit therefore depends upon the product of its inductance and capacity.

The foregoing are, I believe, the more important of the fundamental facts necessary to an understanding of the subject matter of the Marconi and the Lodge patents in suit and if they are borne in mind the comprehension of the subject matter of the patents will be facilitated.

7. Question. Please explain first the particular scientific nature of the invention set forth and illustrated in the Marconi reissue patent No. 11913, as claimed in claim 3 thereof, and the way the devices of said invention function or operate; second the particular scientific nature of the inventions illustrated and described in the Lodge patent in suit, No. 609154, as claimed in claims 1, 2, and 5 thereof, and the way the devices and elements of said inventions function or operate; and third, the particular scientific nature of the inventions illustrated and set forth in Marconi patent in suit, No. 763772, as claimed in claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20, and the way the elements or devices in said inventions function or operate, defining and explaining such technical and scientific terms found in those patents which you may not have already explained, and referring in your answer to any exhibits introduced herein and making any drawings or sketches which may simplify your explanation.

*   *   *   *   *   *   *

Answer. *Marconi reissue patent No. 11913.*—The Marconi reissue patent No. 11913, as I understand it, discloses ways of organizing and operating electrical apparatus so as to constitute a means of producing and propagating electric waves and for receiving and detecting the existence of such waves at a distant station, together with means for cor-elating the waves so as to form an intelligible code of signals, whereby wireless telegraphy may be practiced.

The patent sets forth a number of forms of apparatus at the transmitting and receiving stations, respectively, but the descriptive recital of claim 3, to which my attention is called, applies to only one of these, namely, that more particularly described with reference to Figures 10 and 11. I will therefore deal only briefly with the others.

[fol. 285] The introductory portion of the specification, which is found on page 1, states, in substance, that the invention relates to the transmission of electrical signals by means of oscillations of high frequency, known as "Hertz rays" or "Hertz oscillations"; that is, to what are at the present time commonly referred as "Hertzian" or electric waves, and by this means the patentee states that all line wires such as are used in ordinary telegraphy may be dispensed with.

The specification states (page 1, line 16) that at the transmitting station the patentee prefers to employ a Ruhmkorff coil, having at its primary circuit a telegraph instrument known as a Morse key or other signaling device, and at it poles appliances for producing the desired operation. He says, however, that the Ruhmkorff coil may be replaced by any other suitable source of high tension electricity. The Ruhmkorff coil is diagrammatically indicated in the drawings, as for instance, Figures 1, 9, and 10, at *c*. As already stated, this is a device consisting of two coils of wire, associated with one another upon an iron core. One of these coils is short and of heavy wire, and is known as the primary circuit; the other is known as the secondary coil, and consists of a very large number of turns of fine wire. The two ends are led out to the terminals, referred to in the specification, which are indicated at *c'*, Figure 1. The telegraph instrument is shown in Figure 1 at *b*, and the source of current is indicated diagrammatically as a battery *a*. The telegraph instrument and battery are connected in the primary circuit and there is also a circuit in-

terrupter c^3, connected in this circuit. It consists of a pair of contacts, one of which is caused to vibrate by the magnetism produced in the iron core of the coil, the other of which is rotated by a small motor c^4, this being merely a device to prevent the contact points from sticking together.

After suggesting an alternative arrangement the specification refers, page 1, line 33, to the receiving station and points out that there is there located a local battery circuit containing any ordinary telegraph-receiving instrument, together with an appliance for responding to the received signals.

Transmitting apparatus: The specification then proceeds to describe three general arrangements of the transmitting and receiving apparatus. The first is that shown in Figures 1, 2, and 2a, which show a transmitter apparatus for comparatively short Hertzian waves, arranged to be projected in a definite direction by means of a reflector.

To this end the high-tension terminals c' of the inductance coil c are connected to an oscillator and spark producer, more fully shown in Figure 2a, comprising a series of spheres *d, e,* four in number. When the outer spheres *d* are charged by the coil, when the operator presses the telegraph key, the electrostatic field, such as I have already [fol. 286] described in my foregoing answer, is set up between these balls and a certain amount of energy is thus stored as a result of the ether strain thereby produced. According to the description, the apparatus is so arranged that a spark passes across through the sphere *e*, thereby causing a collapse of the electrostatic field and the production of Hertzian waves of so short a wave length that they may be directed in any direction by means of the metallic reflector *f* (seen in plan view in fig. 2 and in front view in fig. 1). The electric oscillation of energy between the balls *d, e,* will continue until all of the energy has been dissipated either as electric waves or as heat, and thus a train of waves will be sent out. There will be one such train of waves for each charge imparted to the oscillator, and there will in general be one charge for each vibration of the interrupter c^3. By holding the telegraph key *b* closed for a longer or shorter time a larger or smaller number of these trains or groups of waves will be sent out, and thus a group comprising a considerable number of these wave trains corresponds to a dash in the telegraph code and a smaller number to a dot.

Receiving apparatus: The apparatus at the receiving station is indicated in Figures 4 to 8, the arrangement of Figure 4 being the particular receiving apparatus designed to operate with the transmitter of Figure 1. In this figure the receiving apparatus is located in a similar parabolic reflector, similar to that used at the transmitting station. The receiving apparatus itself comprises a pair of plates, *k*, which are constructed of such a length as will make them adapted to the reception of waves of the particular length being transmitted. This is described in the specification, page 3, but, as it is not a part of the subject matter of claim 3, I will not dwell upon it.

Between these plates *k* is located a sensitive tube *j*, which, in the particular form described in detail on page 2, consists of a small glass tube with silver plugs fitted into it and having between the plugs a few filings of silver and nickel mixed. This particular form of wireless telegraph detector is particularly adapted for use where it is desired to have a printed record of the messages.

Associated with this sensitive tube *j* is a local circuit consisting of a battery *g* and the telegraph instrument *n*. This telegraph instrument, in its turn, controls another battery *i* and a suitable printing device *h*. The plates *k* constitute the means of receiving the electric waves, and the sensitive tube the means for detecting the fact that they have been received. In its normal or unaffected state the tube *j* has a very high resistance, so that the battery *g* is unable to send through it any appreciable or significant amount of current. When, however, electric waves are received the sensitive tube immediately changes its resistance to a lower value, so that a sufficient current flows from the battery *g* to actuate the telegraph instrument or relay *n*, which thereupon actuates the printer *h* to initiate the recording of a dot or dash.

The detector: The particular detecting device *j*, used when it is the purpose to record the printed message, is one which having once had its resistance lowered by the [fol. 287] reception of an electric wave remains at that lowered resistance until restored to its initial condition. This is done by tapping or jarring the tube by means of a tapping device *p* seen just above the sensitive tube in Figure 4. The particular details of construction of this tapping device, I understand, are immaterial for present purposes and it will be sufficient to say that it is connected

with the telegraph instrument n and battery r, so that upon the detection of a received wave the tapper is set in operation, thus restoring the sensitiveness of the tube unless electric waves are continuing to arrive, in which case the resistance is reduced by the electric wave as fast as it is restored by the tapper and the printing instrument continues the making of a dot or dash as long as the waves continue to arrive.

Modifications and details of apparatus: A modified arrangement of the transmitting station is shown in Figure 9 where two plates t' are shown suspended in the air from an upright framework t t'. This arrangement produces longer waves and is stated by the specification to be useful where greater distances are to be covered than could be effectively reached by the short wave apparatus of Figure 1.

Figure 10 shows another transmitting arrangement, and this as I understand it is the form designated by the description of claim 3 referred to in the question. In this form of apparatus the spark producer d, e is connected to a vertical wire, which terminates in an elevated capacity areas in the form of a plate u and at its other end is connected to the earth at e. The Rhumkorff coil or source of high-tension electricty c is connected to the two terminals of the spark-gap device and the telegraph-key apparatus is supposed to be associated therewith, as in Figure 1. Upon the closing of the key the source of current is set in operation and a high potential electric charge is communicated to the elevated conductor system, and upon the passage of the charge to the elevated conductor an electrostatic field is produced, as is indicated in Figure 3 of Exhibit No. 92.

Upon the passage of a spark across the spark gap, which will occur as soon as the elevated conductor is fully charged, the passage of the charge to earth takes place and electric waves are set free by the resulting oscillations of current in the antenna, these being such waves as are indicated in Figure 9 of Exhibit 92.

The electric waves caused by this arrangement of Figure 10 are somewhat different in form from those caused by the transmitter of either Figure 1 or Figure 9, since those produced by the arrangement of Figure 10 are sometimes referred to as earthed waves, while those due to the arrangement of Figures 1 and 9 are free waves. To illustrate

this difference in form I refer to Figures 31 and 33 of Exhibit 78, being Manual of Wireless Telegraphy for the Use of Naval Electricians, 1913 edition, as found on pages 60 and 62 thereof. Figure 31 shows free electric waves sent out by an oscillator which is not connected to the earth, while Figure 33 shows the earthed waves radiated from an oscillating system which is connected to the earth.

[fol. 288] Figure 11 of the Marconi patent, No. 11913, shows diagrammatically the arrangement of the sensitive tube in connection with the antenna circuit. One end of the tube is connected with a vertical wire terminating in a plate or capacity area *w*, while the other end is connected to earth, and connections *k'* are shown leading to the local circuit apparatus, which is similar to that already described with reference to Figure 4.

The earth connected arrangements, shown in Figures 10 and 11, are those which have proved particularly useful in practical wireless telegraphy, and the specification points out particular advantages of this arrangement. For example, it is pointed out on page 4, line 25, that the larger the capacity areas *u* and *w* and the higher they are raised above the earth, the greater is the distance at which it is possible to communicate. It is for this reason that present-day wireless telegraph stations designated to communicate over great distances have very large capacity areas, elevated to a great height.

Again it is pointed out in the specification at page 4, line 130, that it is not necessary with this arrangement to have the two stations in view of each other, but that signals may be transmitted even though there are intervening mountains. By this means, therefore, it is possible to overcome the curvature of the earth so that stations at great distance from one another may still communicate, even though the curvature of the earth intervenes to prevent one station from being visible from the other. I may note in this connection that the words found on page 4, line 132, "in view of each other," do not in an electrical sense imply human vision, because electrically the transmitting and receiving station would be in view of each other, even though there might happen to be buildings between, because ordinary building structures are transparent to the electric waves, just as glass is transparent to light. Obstacles like mountains, however, are not transparent to the waves, and two

stations separated by a mountain or by the curvature of the earth are not in view of each other in the electrical sense. This is what I understand the descriptive matter to mean in saying that the arrangement of Figure 10 does not require that these stations should be in view of each other but that communication may be carried on even though mountains intervene.

I have pointed out in considering Figure 4 that the patentee directs that the receiving plates *k* should be so adjusted that the whole circuit comprising these plates and the detector will be in tune with one another and the patentee refers to them as tuning plates. In the same way he also directs that the elevated conductors Figures 10 and 11 should be tuned to one another. Thus at page 1, line 49, he refers to the plates as "preferably electrically tuned with each other," and in describing the structure on page 4, line 123, he speaks of the elevated conductor *w* as "preferably similar to *u*." The patentee explains on page 3 that the maximum effect at the receiving station will be obtained when this tuned construction of the receiving and radiating devices is carried out.

[fol. 289] Mode of operation: The specification on page 5, lines 39 to 94, describes the operation of the apparatus as follows:

"The operation of my apparatus and system of communication or signals is as follows: The Ruhmkorff coil or other source of high-tension electrically capable of producing Hertz oscillations being in circuit with a signaling instrument—such as a Morse key, for instance—the operator by closing the circuit in the way commonly employed for producing dots and dashes in ordinary telegraphy will cause the oscillator to produce either a short or a more prolonged electric discharge or spark or succession of sparks, and this will cause a corresponding short or more prolonged oscillation in the surrounding medium corresponding in duration to the short or longer electrical impulse which in ordinary telegraphy produces a dot or dash. Such oscillations of defined character will thereupon be propagated as such throughout the medium and will affect a properly constructed instrument at a distant receiving station. At such station the imperfect contact instrument is in circuit with a relay, and when oscillations from the transmitting station reach and act upon such imperfect contact, its resistance is reduced, and the circuit is thereby closed during the con-

tinuance of the oscillation and for a length of time corresponding thereto. The closing of the relay circuit causes the sounder or other signal apparatus to act in accordance with the particular oscillation received, and the oscillation also immediately starts the action of the shaking or tapping device, which so shakes the powder in the imperfect contact instrument as to cause it to break circuit as soon as the oscillation ceases which has closed the circuit and produced a movement of the signaling instrument corresponding thereto. I am therefore enabled to communicate signals telegraphically without wires by thus artificially forming oscillations at the transmitting station into definite signals by means of a signaling instrument and receiving and reading the same at a receiving station by an imperfect contact instrument, which when acted upon by such defined oscillations operates, first, to close the circuit in accordance with the received oscillation and produce a corresponding movement of the receiving instrument, relay, or sounder, and also to operate a shaking device to automatically reopen the circuit immediately after the reception of each oscillation, thereby preserving the results of its defined character in the action of the receiver."

In this description the sensitive tube is referred to by the alternative term "imperfect contact instrument," and the telegraph instrument at the receiving station is referred to as a "relay," while the apparatus *h* is referred to as a "sounder or other signal apparatus."

Simplified diagrammatic showing: Plaintiff's Exhibit 99 shows in the figures, under the heading "Marconi reissue No. 11913", the transmitting and receiving apparatus of Figures 10 and 11 of the Marconi patent, which I have just been considering, in simple diagrammatic form, employing colors to designate the different portions of the apparatus. In this figure the vertical wire is indicated at *a* with the capacity areas at the top, these two being connected to the upper terminal of the spark producer G, and the lower terminal of this spark producer is connected to the earth at E. These are shown in black. The yellow circuit of this diagram shows the source of electrical power, by which the [fol. 290] antenna is charged. It comprises the transforming device *c*, or Ruhmkorff coil, a battery or suitable source of current *a*, and telegraph key *b*. The receiving station has a similar elevated conductor connected to one end of the sensitive detector T, whose other end is connected to

the earth at E. The green lines indicate diagrammatically the local circuit, B being the local battery, R the sounder or other signal apparatus, C″ and C^2 are the protective coils described in the specification.

Referring to the terms employed in claim 3, I understand that the spark producer is shown at *d, e,* in Figure 10 and diagrammatically at G in Exhibit 99. The earth connection to one end of the spark producer is shown at E in both figures, and the insulated conductor connected to the other end is shown in Figure 10 by the vertical wire and capacity area *u* and in exhibit 99 by the vertical wire A and capacity area *f*. The imperfect electrical contact at the receiving station is shown at *j*, in Figure 11, and at T in Exhibit 99. The earth connection to one end of the imperfect contact is shown at E, and the insulated conductor connected to the other end is shown as the vertical wire and capacity area *u* in Figure 11, and as the vertical wire A and capacity area *f′* in Exhibit 99. The circuit through the contact is that fragmentarily indicated in Figure 11, at *k, k′*, and more fully shown in Figure 4, and it is the green circuit in Exhibit 99. The terms "spark producer" and "imperfect electrical contact," used in claim 3, designate, as I understand, the same parts as referred to by like terms in the specification. The spark gap, as shown at *e, e,* in Figure 9 and *d, e, e, d,* in Figure 10, is the spark producer, a device for permitting the passage of the spark, as I have already described. The imperfect electrical contact is the sensitive tube device, namely, a device for detecting the arrival of electric waves, in this instance a device for changing the electrical resistance of a circuit and so enabling a local indication of the signal to be given.

Lodge patent No. 609154.—I have already explained how it is that the rapid oscillation of electrical energy in the elevated conductor system of the Marconi patent 11913 gives rise to the production and radiation of electric waves. In practical experience the arrangement of this early Marconi patent, being in general such an arrangement as is shown in the first figure of Exhibit 99, reproduced above, has proved so efficient a radiator of electric waves that the entire energy which could be imparted to the antenna was radiated in a very few swings. The antenna, in other words, so rapidly parted with its energy to the atmosphere —that is, to the ether—that after a few oscillations there

was no further energy left. Just as a ship's propeller parts with its energy to the water and stops revolving as soon as steam is shut off—that is, after a very few turns—so that antenna parted with its energy by sending it out into space after a very few oscillations, and had to be again charged before another train of waves could be produced.

General arrangement of apparatus: The Lodge patent, to which my attention is directed in the second portion of the seventh interrogatory, is directed to the incorporation in such a wireless telegraph system of means for prolonging the oscillations. In Figure 1 of the Lodge patent, there is [fol. 291] shown what the patent calls "a complete installation of Hertzian wave telegraphy * * * in its simplest form" (page 1, line 62). It will be seen that this is a slightly modified form of an arrangement similar to Figures 1 and 4 of the Marconi reissue patent. Such an arrangement, Lodge says, page 1, line 72, will "emit one or two waves before they are damped out," i. e., before the charge is all dissipated.

The Lodge patent points out that the difficulty with an arrangement emitting very short wave trains, having only a few waves, is that the receiving station is not as effectively acted upon as it might be with more waves and that other receiving stations not intended to receive a message are more affected by it than they ought to be. This, Lodge explains, is because the energy is radiated in too few oscillations, hence the wave trains are too short.

To overcome this difficulty he proposes two general arrangements which correspond, respectively, to the arrangement of Figures 9 and 10 of the Marconi reissue patent, in that one arrangement has two elevated capacity areas and has no earth connection and the other has one elevated capacity area, while the other terminal is connected to earth. These may be taken as typically illustrated in Figures 5 and 7 of the Lodge patent, and the general commercial arrangement is shown in Figure B of plaintiff's Exhibit 99, which I will use as a convenient means of description, since the circuits are distinguished by colors.

* * * * * * *

Before referring to the earth-connected type shown in Figure 7 of the Lodge patent and others, and illustrated in simplified diagram in Figure B of Exhibit No. 99, I call attention to Figure 5, which is the nonearthed form. This

figure shows at the left a transmitting and at the right a receiving station. Two capacity areas, which correspond to the areas c^2 d^2 of Figure 9, Marconi patent 11913, already explained, are in Lodge's Figure 5, represented by two opposed metallic cones, *h*, *k'*, between which is located the spark producer in the case of the transmitter and the detecting device in the case of the receiver.

In Figure 7 of the Lodge patent the elevated conductor or capacity area is shown at *h* and corresponds to the elevated capacity area *u* of the Marconi patent 11913, Figure 10, already explained. In Figure B of Exhibit No. 99 this capacity area is indicated at *f* in the transmitting station *f'* in the receiving station.

The Lodge coil, its arrangement, function, and effect: The feature of construction which Lodge added is the coil of wire h^4 of Figure 7, which in Figure B of Exhibit No. 99 is marked *g* at the transmitting station and g^1 at the receiving station, and sometimes termed a "loading coil."

[fol. 292] The effect of this coil is very remarkable in that, assuming a given quantity of energy to be imparted in the form of an electric charge to the elevated conductor, this charge will, in the absence of the coil h^4 be radiated in a very few waves, whereas when the coil is present the same charge will be radiated in a much greater number of waves.

In the accompanying sketch which I have drawn I have roughly indicated the effect of this Lodge coil. In this sketch the upper figure, *a*, illustrates the radiation of 3 waves from an antenna, not provided with a Lodge coil, and the lower figure, *b*, a train of 12 waves, such as might be produced by the radiation of the same energy from the same antenna when provided with such a coil. This sketch I have marked "Waterman sketch No. 1, effect of Lodge coil." It should be understood that this is merely a free-hand sketch and hence is not to scale.

Referring further to Figure 7, it will be observed that the spark producer consists of a spark gap having ball terminals h^2 h^3; that on one side of this spark gap there is inserted in the antenna a coil of wire of a few turns h^4, mounted upon an insulator *y*, within the coil. From the two spark gap terminals wires not lettered lead off as appears from the description to the source of power, which the Lodge patent says may be a Ruhmkorff or a Tesla coil, or a

Wimshurst or other known or suitable high-tension machine.

In plaintiff's Exhibit No. 99, Figure B, the arrangement is shown with the elevated conductor *f*, inductance coil *g*, spark producer G, and earth connection E, in black, and the power source consisting of a Ruhmkorff coil or transformer *c*, a battery *a*, and a key *b*, drawn in yellow. At the receiving station, Figure B, Exhibit 99, which is arranged according to Figure 3 of the Lodge patent, which is a fragmentary drawing only, the capacity area *f'*, inductance *g'*, and earth connection *e* are shown in black, while the detector circuit comprising the detector T, indicator R, and battery B is shown in green.

I have already explained that the wave length radiated from a given antenna depends, like the period of vibration of a mechanical body, upon its inductance and capacity, corresponding to its weight or inertia and its elasticity. The Lodge inductance coil h^4 in the patent drawings and *g* in Exhibit No. 99 possesses a considerable amount of inductance, and hence the insertion of such a coil in a given antenna structure adds to the total inductance of that structure and increases the wave length.

This Lodge coil therefore has two effects upon the wireless telegraph transmitter: First, it increases the number of waves which will be radiated as the result of a given charge imparted to the antenna, and, second, it increases the wave length which the radiated waves will have.

To bring out more clearly the effect of this coil, I call attention to the fact that the wave length of an antenna could be increased by simply making it higher. This would increase the length of the wire, and hence the inductance, and to some extent the capacity, and so increase the wave length. To increase the wave length in this manner, however, would not materially affect the number of waves radiated for a given energy imparted to the antenna. Taking the crude analogy which I suggested of a propeller wheel revolving in the water, it is evident that a propeller could be [fol. 293] made to revolve more slowly for a given power driving it by merely making it larger and hence heavier, but this would not cause it to revolve an appreciably longer time after steam was cut off from the engine driving it. If, however, a flywheel were added to the propeller shaft inside the ship, then, upon cutting off the steam, the propeller would continue to revolve much longer, notwithstand-

ing the fact that its motion would be resisted by the water surrounding it which would absorb its energy.

In a similar manner to that suggested by this rough analogy, the Lodge inductance coil placed in the antenna acts as a local storage means for energy in a way which could not be effected by merely increasing the size of the antenna, and so causes a longer train of waves to be radiated.

As shown by Waterman sketch No. 1, the waves radiated from an antenna without the Lodge coil will at first be more powerful than those radiated from the same antenna with the same charge after the Lodge coil has been inserted. This is because the same amount of energy is in this case spread out in a larger number of waves. This will not necessarily have the effect of decreasing the distance at which communication can be effected with a given amount of energy, because at the receiving station there will also be such a Lodge coil, which will more effectively gather and conserve the energy on account of the larger number of waves.

The greatest practical advantage of the Lodge construction, however, is the greater accuracy of tuning which is possible; that is to say, the more perfectly can the signal from a given transmitting station be restricted to the particular receiving station for which it is intended and the less will be the effect on other receiving stations tuned to different wave lengths.

Thus by employing this Lodge construction in each of a number of transmitting and receiving stations, but arranging them for different wave lengths, interference between messages is very much reduced.

This matter is of so much practical importance that Congress has by law forbidden the use of a so-called broad wave—that is to say, of a transmitter radiating only a very few waves—and has required that longer wave trains shall be used to reduce interference between stations, the shortest wave train permitted being one having 24 waves, or twice the number shown in Figure B of Waterman sketch No. 1.

The presence of the Lodge coil at the receiving station, as shown for example in Figure 5 of the Lodge patent, diagrammatically illustrated in Figure B of Exhibit 99, is also important, for not only does it prevent excessively rapid reradiation and loss of the received energy, [fol. 294] but by giving to the antenna system a stronger tendency to prolonged vibration in a definite period, that

is with a definite frequency or rate of vibration, it enables the antenna to resist being set in vibration by received waves of other frequencies to which it is not intended to respond.

Thus at both stations the insertion of the Lodge coil tends to "syntony," as stated, for example, at page 1, line 101, that is, it tends to the prevention of interference, or conflict of messages between a plurality of stations operating at the same time.

Lodge's variably acting coils: In order that this effect may be under control, and that the same station may at will use different transmitting wave lengths, Lodge describes what he calls "variably acting" coils. Two arrangements are shown in Figures 9 and 10, respectively, that in Figure 9 providing means for cutting out a portion or portions of the winding, constituting the coil h^4, and that of Figure 10, consisting in the arrangement of a plurality of coils, any one of which may be cut into service by means of a switching device, shown in Figure 11, diagrammatically indicated in Figure 10, at the point A^1, B^1, C^1. In Figure B of Exhibit 99, means for varying the number of turns in service of Lodge coils g, g', are indicated by the arrows at 1 and 3, respectively, the method of varying being that illustrated in Figure 9 of the Lodge patent.

The Lodge patent also provides for the use of the antenna at a wireless telegraph station either for the purpose of transmitting or for receiving. Figure 3, for example, shows fragmentarily the portion of the apparatus within the station as arranged for transmitting or receiving. As shown, the transmitting spark gap, h^2, h^3, is cut out of action or short-circuited by a switch h^9, and receiving apparatus, consisting of a detector e, battery f, and indicator g, which the specification indicates may be either a telegraph instrument or a telephone. Means for charging the same antenna at the transmitter are also shown at h^6, h^7.

Lodge's claims 1, 2, and 5: Claim 1 of the Lodge patent reads as follows:

"1. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, of a self-inductance coil inserted between them electrically for the purpose of prolonging any electrical oscillations excited in the system and constituting such a system a radiator of definite frequency or pitch."

Referring to the plaintiff's Exhibit 99, Figure B, the pair of capacity areas is constituted by the elevated structure f, E, at the transmitting station, and f', E, at the receiving station, and in Figure 7 of the Lodge patent, by the elevated conductor h, and the earth, to which the lower end is described as connected.

The Lodge patent explains in a number of instances that the earth may constitute one of the capacity areas. For example, at page 2, lines 96 to 107, it is stated:

"As charged surfaces or capacity areas spheres or square plates or any other metal surfaces may be employed; but I prefer, for the purpose of combining low resistance with great electrostatic capacity, cones or triangles or other such diverging surfaces with the vertices adjoining and their larger areas spreading out into space; or a single insulated [fol. 295] surface may be used in conjunction with the earth, the earth or conductors embedded in the earth constituting the other oppositely-charged surface."

Various arrangements of capacity areas are shown. Thus, two conical capacity areas, without earth connection, are shown in Figure 5. A single vertical plate with earth connection is shown in Figure 6, a horizontal plate with earth connection in Figure 7, and a rooflike structure in Figure 8.

Referring further to claim 1, the "self-inductance coil inserted between them electrically" is illustrated in Figure B of Exhibit No. 99, by the coils g, g', and in the figures of the patent by the coil h^4. This coil is, as the patent states, for the purpose of prolonging electrical oscillations excited in the system and constituting the system a radiator of definite frequency or pitch. This latter expression means that it is one which radiates or responds to a more prolonged series of waves so as to affect or be affected very little by other stations.

Claim 2 reads as follows:

"2. In a system of Hertzian-wave telegraphy the combination with a pair of capacity areas, of a self-inductance coil inserted between them electrically for the purpose of prolonging any electrical oscillations excited in the system, thus constituting the system a resonator or absorber of definite frequency or pitch, and a distant radiator of corresponding period capable of acting cumulatively."

Claim 2 is similar in its description to claim 1, save for the last clause, which calls for a distant radiator of corresponding period capable of acting cumulatively. The specification explains that the insertion of the Lodge coil in the antenna system enables it to act cumulatively if it has the same natural period of vibration; that is to say, if the coil h^4 therein is so adjusted that the whole antenna system will have any charge communicated to it set into vibration at the same period as that of the received waves; for example, the specification says, page 3, lines 92 to 101:

"The receiver or resonator consists of a similar pair of capacity areas connected by a similarly shaped conductor or self-inductance coil, the whole constituting an absorber arranged so as to have precisely the same natural period of electrical vibrations as the radiator in use at the corresponding emitting station, so that it can accumulate the received impulses; that is to say, can act cumulatively."

Claim 2 thus adds to the recitation of claim 1 a distant radiator adjusted to the period of the receiving station and capable of acting cumulatively.

Claim 5 reads as follows:

"In a system of Hertzian-wave telegraphy the combination, with a pair of capacity areas, of a variably-acting self-inductance coil serving to syntonize such a radiator or resonator to any other such resonator or radiator, whereby signaling may be effected between any two or more correspondingly-attuned stations without disturbing other differently-attuned stations."

Claim 5 refers descriptively to the same elements heretofore defined, but specifies that the self-inductance coil shall be variably acting, as illustrated in the drawings and set forth in the specification, particularly on page 3, lines [fol. 296] 72 to 91, whereby, as the claim describes, signaling may be effected with any one of several other stations without disturbing the stations tuned to different frequencies. In Exhibit 99, figure B, these variably acting coils are shown at *g*, *g'*, with the variable means indicated by arrows 1 and 3, respectively, for making the adjustment referred to in claim 5. As I have already pointed out, such means are shown in the patent in figures 9 and 10.

Marconi four-circuit or tuning patent No. 763772.—The specification of this patent states in the opening paragraph of the description, page 1, lines 10 to 20:

"My invention relates to apparatus for communicating electrical signals without wires and by means of Hertz oscillations or electric waves; and the object of the invention is to increase the efficiency of the system and to provide new and simple means whereby oscillations or electric waves from a transmitting station may be localized when desired at any one selected receiving station or stations out of a group of several receiving stations."

It appears from this statement that this invention of Marconi's also relates to telegraphy without wires by means of electric waves and that it has two objects, namely, to increase the efficiency of the system, by which he means, as appears from other portions of the specification, not only the economy but the effectiveness of a wireless telegraph system, and, second, to improve the ability to localize messages at an intended receiving station, with reduced interference with other stations.

The elementary diagrams of the arrangement are shown in Figures 1 and 2, wherein Figure 1 is the transmitting station diagram and Figure 2 the receiving station diagram.

It will aid the understanding of the patent to note at once that (referring to fig. 1) there is the elevated capacity area *f*, connected by a wire *a* to a variably acting inductance coil *g*, which in turn is connected to the earth at E just as already described with reference to the Lodge patent, and that similarity, with respect to the receiving station, there is (fig. 2), the elevated capacity area *f'*, connected by wire A, to variably acting inductance coil *g'*, which in turn is connected to the earth at E, being again the receiving arrangement of the Lodge patent, No. 609154, just above considered.

I therefore understand that Marconi starts with the syntonic arrangement of Lodge and that it is the efficiency and syntony, or selectively, as it is sometimes called, of this arrangement which his invention is designed to improve, as set forth in the above-quoted paragraph.

The specification, comparing the arrangement of the present invention with that of the earlier Marconi patent (page 1, lines 20 to 47), states as follows:

"In my prior United States patent No. 586193 (reissue No. 11913, dated June 4, 1901) I have shown and described the combination at a transmitting station of an oscillation producer, such as an induction coil, having one end of its secondary coil connected to one contact of a spark producer and to the earth and having the other end of the said secondary connected to the opposite contact of the spark producer [fol. 297] and to a vertical wire or elevated plate, and I have further shown at a receiving station an imperfect contact connected in circuit with a vertical receiving wire and with the earth. According to the present invention the system includes at the transmitting station the combination with an oscillation transformer of a kind suitable for the transformation of very rapidly alternating currents, of a persistent oscillator, and a good radiator, one coil of said transformer being connected between the aerial wire or plate and the connection thereof to earth, while the other coil of the transformer is connected in circuit with a condenser, a producer of Hertzian oscillations or electric waves shown in the form of a spark producer, and an induction coil (constituting the persistent oscillator) controlled by a signaling instrument."

Referring to Figures 1 and 2, the oscillation transformer referred to, consists in Figure 1 of the coils *d*, *d'*, the latter consisting of two turns of wire being in the antenna itself, while the coil *d*, consisting of a single turn of wire, is connected in a local circuit. Similarly, in Figure 2 the oscillation transformer consists of the coils j', j^2, the former being connected in the antenna circuit and the latter (which, as shown, is divided into two windings) is located in a local circuit, there being four oscillatory circuits, two in the transmitter and two in the receiver.

Referring to Figure 1 or, for convenience, to Figure C of Exhibit No. 99, which is identical with Figures 1 and 2 of the Marconi patent, save for the use of colors to distinguish the circuits, the coil *d* is seen to be connected in a local circuit comprising also a condenser *e* and a spark gap, not lettered in the patent, but marked "G" in Exhibit No. 99. This circuit is indicated in red, in Exhibit No. 99, and so is easily identified.

Transmitting apparatus and station: I call particular attention to the difference between these two circuits at the transmitting station. The black, or antenna, circuit in-

cludes one coil (d') of the oscillation transformer, and the coil g, and is connected at the top to the elevated capacity area f, while at the bottom it is connected to earth. The two ends of the circuit in other words do not approach one another closely, but are widely separated, and the circuit is what is known as an open circuit. The red or local circuit, on the other hand, comprises the coil d, condenser e, and spark gap G. This red circuit is therefore a circuit which, when current is flowing across the spark gap, is a completely closed circuit.

These two sorts of circuits have very different properties.

Good radiator and persistent oscillator: I have already explained by diagrams how an antenna circuit connected to earth, as are these antenna circuits of the Marconi patent, produces a widely extending electrostatic field, which, upon collapsing, gives rise to and emits electric waves, and, in explaining the Lodge patent I have called attention to the fact that such a circuit is too perfect a radiator of such waves, so that for practical purposes it is used in conjunction with the Lodge coil to make it radiate more sustained wave trains.

The closed circuit, shown in Figure 1 of the Marconi patent, and that indicated in red in Figure C of Exhibit No. 99, on the other hand, has its capacity concentrated in [fol. 298] the condenser e. It therefore produces no external electrostatic field that is appreciable, and hence the oscillation of current in such a circuit does not produce electric waves.

One of these circuits, namely, the black circuit of Exhibit No. 99, therefore, possesses in large measure a property which the other, namely, the red circuit, does not possess at all, and for this reason the open or black circuit loses its energy by sending it off into space while the closed or red circuit by itself can not radiate any of its energy, but the current will oscillate in the circuit until consumed by the resistance of the circuit, including that of the spark gap.

For this reason the open or radiating type of circuit has sometimes been called a "good radiator" or a "radiating circuit," while the other or closed type has sometimes been referred to as a "persistent oscillator" or "non-radiating circuit" to distinguish it from the radiating oscillator or open circuit.

This is what is meant in the above quoted portion of the specification, as I understand it, by the use of the expression "a persistent oscillator" and "a good radiator." Both circuits contain inductance and both contain capacity, hence both may be able to cause charges imparted to them to oscillate, but one circuit can discharge its energy in the form of electric waves and the other can not.

These two circuits Marconi associates by placing the coils *d* and *d′* sufficiently close together, so that one can experience the magnetic effect of the other, and the two thus become an oscillation transformer and are so designated in the above-quoted passage from the specification.

Oscillation transformer: Marconi's purpose in associating these two opposite kinds of circuits is, as will appear from portions of the specification to be referred to, to have one circuit proportioned and devoted to the storage and setting in oscillation of a desired quantity of energy larger than could conveniently be imparted to the other circuit, and another circuit proportioned to have the desired radiating qualities without being restricted in its construction by having to directly receive and store all of the energy, but which it is capable of taking and radiating that energy from the first circuit.

The means of transferring this energy from the first or closed circuit to the second or open circuit is the association of inductance coils in the two circuits in such a manner as to constitute an oscillation transformer. The coils *d d′* are the two inductance coils so associated.

As I have already explained, currents flowing in a wire create a magnetic field which appears when the current appears and disappears when the current disappears. It is a well-known physical fact that conversely if a magnetic field can be made to appear in the vicinity of a coil or circuit in which a current can be set up a current will in fact be created and when the magnetic field disappears a current in the reverse direction will be created. Broadly considered this is the principle upon which mechanical generators of electricity are built and upon which induction coils, transformers, and oscillation transformers operate. It is known as the principle of electromagnetic inductance.

In ordinary transformers, such as are used as sources of power and for electric lighting and the like, the mag-
[fol. 299] netic field is set up by currents flowing in one

coil surrounding an iron core, and the second or induced current is caused to be produced in another coil wound on the same core, and in general the characteristics of this second current depend upon the ratio of the number of turns in the second coil as compared to the first. If, for example, the first coil having a certain number of turns is supplied with current having a quantity of, say, 10 amperes which is forced through the coil by a pressure or voltage of 100 volts, then if the second coil has ten times as many turns, the current produced in that second coil will have ten times as high a pressure, namely, 1,000 volts, but only one-tenth as much current, namely 1 ampere.

In the sort of transformer, which Marconi calls an oscillation transformer and which is used in wireless telegraphy, this relation existing in ordinary transformers does not hold, and the particular characteristics of the current produced in the second coil are found not to be determined to any appreciable extent by the ratio of the number of turns, but rather are determined by the characteristics of the two circuits as a whole, and as Marconi later points out, by their resonant relation to one another.

The particular oscillation transformer, which Marconi shows in Figure 1, and more particularly in Figures 3 and 4 has in its primary coil *d* only a single turn of wire and in its secondary circuit only two turns of wire. Notwithstanding this fact, however, the current produced in the open circuit may have an electrical pressure or voltage several or many times as high as that which is introduced into the primary circuit. It is the function of the oscillation transformer to transfer the energy imparted to the primary circuit over into the open or radiating circuit with results determined by the adjustments of the two circuits.

In the receiving apparatus also Marconi shows an oscillation transformer having a primary coil j' in the antenna circuit and a secondary coil j^2 divided into two parts in the local circuit. In his instance the oscillation transformer so constituted is composed for greater convenience of a larger number of turns of smaller size, and the purpose of the transformer is to transfer the energy received by the open antenna circuit of the receiving station over into a local circuit where it is detected and used, and the purpose in this instance also is to permit of the effective construction of the two circuits, the open circuit for effectively receiving the waves and gathering their energy and the

second or local circuit, which also is closed, for the purpose of effectively utilizing this energy, and the action of one circuit upon the other depends upon the proportions and adjustment of the two.

In neither the transmitting nor the receiving apparatus does the oscillation transformer have any iron core and it is characteristic of the transformer of the patent and as used in practical wireless telegraphy that the oscillation transformer have no iron cores.

Continuing the specification, beginning at line 47, page 1, recites the various features found in what he calls "the complete system," and under this heading he recites the presence of the inductance coil such as *g*, *g'*, to which I have already referred, and he says of this complete system, page 1, line 62, "By this arrangement of apparatus I am [fol. 300] able to secure a perfect 'tuning' of the apparatus at a transmitting station and at one or more of a number of receiving stations."

In other words, Marconi states that by such means, assembled as here described, he is able to effectively syntonize the transmitting and receiving stations and accomplish that one of the objects, already referred to in the quoted passage, whereby "electric waves from a transmitting station may be localized when desired at any one selected receiving station."

At page 1, line 77, to page 2, line 5, the transmitting station is described as follows, and reference may be conveniently had to plaintiff's Exhibit No. 99, Figure *c*, transmitting station, reproduced above, which is identical with Figure 1, save for the colors, which will aid in tracing the circuits described:

"The transmitting station is provided under my present invention with a source *a* of current electrically connected in circuit with the primary of an induction coil *c* and with a circuit-closing key *b* or otherwise controlled by a signaling instrument. In the secondary circuit of said induction coil the spherical terminals or other contacts of a spark producer are included with a shunt therefrom, in which shunt is included the primary coil *d* of an oscillation transformer such as d^2. A condenser *e*, preferably one provided with two telescoping metallic tubes separated by a dielectric and arranged to readily vary the capacity by being slid upon each other is included in one

connection from the induction coil to the transformer winding *d*. The secondary coil *d'* of the transformer is connected (at one end) to the earth E and at its other end to a vertical wire A or an elevated plate *f*.

"It is obvious that instead of the induction coil and associated parts for producing the electric waves or oscillations I may use any other proper means for producing such waves or oscillations such, for instance, as a generator of alterating electric currents."

Referring to Exhibit No. 99, the yellow circuit comprising the battery or alternating current generator *a*, referred to above, the operator key *b* and the induction coil or transformer constitute the power source by which a charge of electrical energy is imparted to the red circuit where it is stored in the condenser *e*. To set this energy, which is stored in static or quiescent form, into oscillation a spark producer, shown as a spark gap G, is provided in the circuit.

No specific instructions are given in the specification for the construction of this spark gap, but it is referred to in the above quotation as "a spark producer or other electric wave or oscillation producer," and in practice it is constructed in various specific forms, all having the same general purpose, namely, to suddenly release the energy stored in the condenser and permit it to oscillate in the closed circuit until that circuit has fulfilled its purpose in the structure for the time being, namely, has furnished its stored energy to the antenna circuit to be radiated. In general the spark gap or spark producer consists of two or more terminals of some appropriate form in air or some other gas, and its operation depends upon the property of gases by virtue of which they are very perfect insulators up to a certain point—that is, up to a certain electrical pressure determined by the construction of the gap—but when this point is reached the insulating property of the gas is destroyed and it becomes momentarily conducting, permitting a spark or discharge to [fol. 301] pass, and hence permitting the circuit to oscillate until so much energy has been transferred to the other circuit that the pressure no longer is sufficient to keep the gap in its conducting condition.

Operation of transmitter: The operation of the transmitter is therefore as follows:

Upon the closure of the operating key a current of the desired charging pressure is produced at the terminals of the transformer *c* and flows to the red circuit, thereby charging the condenser *e*. As electrical energy accumulates in the condenser the pressure across its terminals, and hence across the spark gap G, increases until it is sufficient to break down the insulation of the air or gas in the spark gap. At this point the stored energy from the condenser flows across the gap, starting a current which oscillates back and forth in the circuit.

Each such oscillation of current through the coil *d* creates a magnetic field which, acting upon the coil *d'*, sets up a current therein and transfers energy thereto. If the circuits are correctly proportioned and adjusted, as Marconi describes, energy will be effectively transferred and an oscillating current of a desired high pressure will be set up, charging the capacity area *f* to a high potential and causing the alternate development and collapse of an electrostatic field whereby electric waves will be sent out.

The characteristics and properties of the oscillatory circuits: The characteristics of the circuits of transmitter and receiver are described on pages 2 and 3, and on pages 3 and 4 there are specifically described various modes of constructing and associating the circuits for particular illustrative examples. I will refer briefly to the proportioning and adjustment of circuits as set forth on page 2. For example, at page 2, lines 6 to 24, the patentee defines in general the characteristics of the circuit as follows:

"The illustrated arrangment of parts at a transmitting station enables much more energy to be imparted to the radiator *f*, the approximately closed circuit of the primary being a good conserver and the open circuit of the secondary being a good radiator of wave energy. My experiments have demonstrated that the best results are obtained at the transmitting station when I use a persistent oscillator—an electrical circuit of such a character that if electromotive force is suddenly applied to it and the current then cut off electrical oscillations are set up in the circuit which persist or are maintained for a long time—in the primary circuit and use a good radiator—i. e., an electrical circuit which very quickly imparts the energy of electrical oscillations to the surrounding ether in the form of waves—in the secondary circuit."

Further, at page 2, lines 39 to 49, the specification says:

"For the best results and in order to effect the selection of the station or stations whereat the transmitted oscillations are to be localized I include in the open secondary circuit of the transformer, and preferably between the radiator *f* and the secondary coil *d'*, an inductance coil *g*, figure 1, having numerous coils, and the connection is such that a great or less number of turns of the coil can be put in use, the proper number being ascertained by experiment."

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[fol. 302] I call particular attention to the fact that the above-quoted passage referring to "the illustrated arrangement of parts" describes it as based upon Marconi's experiments and as involving the employment of two sorts of circuits, one of which he styles "a persistent oscillator" and the other of which he designates "a good radiator." Further, he defines these circuits respectively. A persistent oscillator is a circuit in which if oscillations are set up by the sudden application of electric charge and the source of charge is then cut off the circuit must oscillate until it is deprived of its energy by some other means than radiation. The other circuit is distinguished from this first circuit in that it has the power to get rid of its energy by radiation and is indeed a good radiator.

As I understand this, it does not say or imply that when the two circuits are associated as shown the oscillations in the primary or closed circuit persist for a long time or for any particular time nor does it say that the open or secondary circuit radiates very rapidly. Indeed, the second quotation above expressly states that "for the best results" the inductance coil *g* is employed for the purpose of preventing too good radiation.

These definitions in the first of the two quotations above distinguish two different kinds of circuits, which are to be associated and they are defined as having two distinguishing properties, namely, one, a circuit which can not radiate and hence must oscillate until its energy is consumed within itself, and the other, one which will not oscillate until it consumed its own energy because it will radiate that energy in space.

What happens when the two sorts of circuits are associated is briefly stated in the passage beginning at line 25 page 2, as follows:

"In operation the signaling-key *b* is pressed, and this closes the primary of the induction-coil. Current then rushes through the transformer-circuit and the condenser *c* is charged and subsequently discharges through the spark-gap. If the capacity, the inductance, and the resistance of the circuit are of suitable values, the discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer and induct similar oscillations in the secondary, these oscillations being rapidly radiated in the form of electric waves by the elevated conductor."

It will be observed that this statement says that upon the closure of the telegraph key, current rushes through the circuit and charges the condenser *c*. It is then stated that "if the capacity, inductance and resistance of the circuits are of suitable values the discharge will oscillate in the circuit. If they are not of such values as to cause oscillation then all the energy will be dissipated in a single rush. How many oscillations exist in the circuit in actual operation therefore depends upon the quantity.

To ascertain what the number of oscillations will be in any practical construction, it is necessary to consider first the relations of these quantities and second the matter [fol. 303] stated in the latter portion of the above quotation, namely, how fast the energy is transferred to "induct similar oscillations in the secondary" or antenna circuit.

Considering first the operative characteristics of the primary circuit, it will be seen from the description of the transformers found on page 3, lines 25 to 47, that the wire of which these transformers are made is of good size and is short in length so that its resistance is quite low. It is therefore clear that the resistance of this primary circuit as determined in accordance with the last quotation almost entirely by the character and adjustment of the spark gap. This is found to be the case in actual practice and the number of oscillations or indeed whether there are any oscillations at all after the initial rush of the current across the gap depends entirely upon the resistance of spark gap.

There is in such a closed circuit or persistent oscillator—that is, nonradiator—another relation which also determines how many oscillations can take place, whether there is a spark gap present or not, and that is the size of the condenser as compared to the size of the inductance coil.

Looking at the drawings, Figures 1 to 4, and at the description of these figures, it will be seen that the inductance coil *d*, which also serves as the primary of the oscillation transformer, consists of a single turn of wire, of comparatively small area. Inductance of the circuit as illustrated is therefore very small indeed, which means that in order that a certain wave length shall be radiated, the condenser must be comparatively very large.

Marconi says, in the last-quoted paragraph, that the oscillatory character of the circuit is determined by the inductance, capacity, and resistance and the relation is such that a large capacity and small inductance means a very few oscillations, as compared to the number that would exist if the reverse were true. To give an idea of these relations, for example, taking the first one of the illustrative examples given in the table on page 4, the wave length of which I have found to be approximately 200 meters, and calculating from the value of the capacity given in the table, I find that assuming the resistance of the spark gap to be 1 ohm, the circuit if oscillating by itself, would have three complete oscillations—if the current continues to oscillate until it fell 1 per cent of its original value. This shows that a circuit such as the patent describes as illustrative of the invention, being number 1 of the table on page 4, may have the capacity, inductance, and resistance of the circuit of such values as to cause a comparatively few oscillations to take place.

When the two circuits are associated, and with the spark gap in operation, the number of oscillations which will take place is less than that which will take place in the same circuit of like capacity and inductance and with a fixed resistance for two reasons. The first is that owing to the resonant relation between circuits hereafter described the oscillation transformer quickly transfers its energy to the antenna circuit in accordance with the above statement of Marconi, "these oscillations being rapidly radiated in the form of electric waves by the elevated conductor." If the energy is thus rapidly taken away from the primary circuit and radiated, it of course results that the number of oscillations in the closed circuit is decreased.

[fol. 304] The second reason why, when the circuits are associated and the spark gap is in operation the number of oscillations in the closed circuit is reduced, is that the passage of the spark across the gap requires that there shall

exist at the spark gap terminals a certain critical voltage, dependent upon the condition of the spark gap and the amount of current which has just previously passed through it. As the circuit oscillates the current decreases, and as the current decreases, the electrical pressure required to cause the current to again pass increases. The oscillation, however, continually reduces the charge in the condenser and so reduces the electrical pressure at the gap, and hence it quickly results that there is no longer a sufficient pressure in the circuit to cause the spark to jump the gap, and the oscillation of current in the circuit therefore ceases as soon as this condition is reached.

Briefly summarizing, therefore, the transmitter of the patent as thus far described consists of a circuit which can not radiate, combined with a circuit which can radiate in such a manner that energy imparted to the first circuit may be transferred to the second upon the flow of current across the spark gap contained in the first circuit. The number of oscillations which can take place in the first circuit is determined for a given wave length or frequency of oscillation by the size of the condenser in that circuit and by the resistance of the spark gap and the number of oscillations which will actually occur in the operation of the apparatus depends upon the characteristics of the spark gap and the current flowing across it and upon how closely the two circuits are associated, and therefore how rapidly the energy is transferred from one circuit to the other. In modern terminology, this association of the circuits one with the other is termed "coupling."

Purpose of two circuits in the transmitter: The purpose of employing two circuits at the transmitter, as above described, is stated in the passage which I have quoted from page 2, line 6, to be that it "enables much more energy to be imparted to the radiator." The reason why it enables more energy to be imparted is, first, that an antenna of given dimensions has a small capacity and hence can have only a small charge imparted to it at a given pressure or voltage, whereas the closed circuit associated therewith can by selecting a suitable condenser have a large capacity, and hence at the same or even at a lower voltage can have a much larger charge and hence "much more energy" imparted to it. The second reason is that by reason of the resonant relation of the circuits, later described in the

specification, the energy can be efficiently transferred to the radiating circuit while radiation is taking place, and hence this larger store of energy imparted to the primary or closed circuit can by this means be effectively converted into electric waves.

The amount of energy that can be imparted to a given antenna in a single charge depends upon the capacity of the antenna and the voltage that can be used to charge it. The size of the antenna is in general determined approximately by the wave length which is to be radiated, and since the size determines the capacity, other things being equal, it is evident that the capacity is fixed by other considerations.

The pressure that can be used to charge an antenna containing a spark gap like that of the early Marconi patent, [fol. 305] reissue No. 11913, is limited by the qualities of the spark gap. If the spark gap is too long its action is irregular, and good signals can not be made. If the spark gap is shorter, then the voltage across it, and hence the charge that can be put in to the antenna, must be reduced, and the signal will be of good quality but weak. Hence the amount of energy, and consequently the distance that could be reached with a given wave length by the original Marconi arrangement having the spark gap in the antenna, was limited by the small capacity of the antenna and the low charging pressure that could be applied to it on account of the presence of the spark gap.

This difficulty Marconi overcame by the association with the antenna circuit of a closed nonradiating circuit, into which he put the spark gap, and into which he could put a condenser of so large a capacity that with a proper spark-gap pressure a much larger electrical charge could be imparted to this circuit than to the antenna circuit direct and by devising a way of efficiently transferring this energy to the antenna circuit, this closed nonradiating primary circuit became a *reservoir* for the antenna.

This "illustrated arrangement of parts at a transmitting station enables much more energy to be imparted to the radiator" for two reasons. First, because the closed primary circuit not being able to radiate of itself and having a large capacity can receive and conserve a much larger charge of electrical energy; and, second, because there being now no spark gap in the antenna the latter can be charged from the primary circuit to a considerably higher

pressure, namely, to such a pressure as the insulation of the antenna will safely take care of. This is a much higher pressure than can be used across a spark gap in the antenna if good results are to be obtained.

Further, the spark gap of itself necessarily involves the production of a large amount of heat, light, and noise, and these all consume energy. With the spark gap in the antenna all the energy thus consumed was taken from the charge which had been imparted to the antenna, and consequently less remained to be radiated. By putting the spark gap in the local circuit and using therein a large capacity it was possibly to supply this necessarily wasted energy as a purely additional energy supply, which therefore did not subtract from and waste energy transferred to the antenna. All that it is necessary to do is to make the condenser in the primary circuit enough larger to receive and store this energy in addition to that received and stored for the purpose of the signal.

It therefore results that by associating with the antenna circuit a reservoir circuit of large capacity in such a manner that the energy of the reservoir could be efficiently transferred to the antenna and the transfer continued while the antenna was radiating until all of the energy transferred Marconi provided the means for imparting much more energy to the radiator, for using the energy so imparted more efficiently, and producing longer and more sustained waves than could be produced when the energy losses of the spark gap had to be subtracted from the energy imparted to the antenna.

He thus attained both of the objects set forth in the introductory statement of the specification, namely, greater efficiency, both in the sense of economy and effectiveness, and greater selectivity; that is, better localization of signals at the intended receiving station to the exclusion of [fol. 306] reception by stations not desiring to receive or desiring simultaneously to receive from some other transmitter.

Resonant transfer of energy: The mere association of a closed circuit having a large capacity, with an antenna circuit, does not of itself enable more energy to be imparted to the radiator, nor would it produce a commercially feasible wireless telegraph system for the reason that it is impossible by this means only to efficiently transfer the energy from the closed to the radiating circuit. To effect the de-

sired result Marconi found that it was necessary to so adjust the inductance and capacity of the two circuits as to give them substantially the same time period of oscillation; that is to say, to put them substantially in resonance with one another. The process of doing this is commonly referred to as the tuning of the transmitter or receiver, as the case may be.

I have already noted[1] the fact that the time it will take the charge to oscillate in any given circuit will depend upon the numerical values of the inductance and the capacity of the circuit, being in fact proportional to the square root of their products. Two circuits are in resonance when they have the same time period of oscillation; that is to say, when electrical charges imparted to them complete one oscillation to and fro in the same length of time. In order that this may be the case it is not necessary that the two circuits have the same inductance and capacity, but that the products of the inductance and capacity in the two circuits should be alike. This is set forth in the specification, more particularly at page 2, line 118, as follows:

> "The capacity and self-induction of the four circuits, i. e., the primary and secondary circuits at the transmitting station and the primary and secondary circuits at any one of the receiving stations in a communicating system are each and all to be so independently adjusted as to make the product of the self-induction multiplied by the capacity the same in each case or multiples of each other; that is to say, the electrical time periods of the four circuits are to be the same or octaves of each other."

The term "self-induction," used in this quotation, is identical in meaning with the more modern term "inductance." The terminology of the electrical art has changed rapidly and new terms are constantly coming into use. This is merely one instance of such change, but there is no confusion introduced thereby in this particular instance, because it so happens that the term "inductance" has been merely substituted for the term "self-induction," and neither has any other meaning. In brief the self-induction or inductance of a circuit is simply the total number of magnetic lines of force cutting the total number of turns or total length of wire for each unit of current flowing in the circuit. The significance of the prefix "self" in the term

"self-induction" is that the magnetic lines, referred to in the definition, are magnetic lines produced by current flowing in the circuit itself, as distinguished from magnetic lines due to a current flowing in some other circuit.

The foregoing statement quoted from the patent therefore states that the circuits are to be adjusted so as to have like products of capacity and inductance in the two circuits so that the two circuits have the same electrical time periods or time periods which are multiples of one another. The [fol. 307] electrical time period of the circuit is, as above noted, the length of time taken for discharge imparted to the circuit to make one complete oscillation to and fro therein.

By this means it is possible for the apparatus illustrated in the patent to effect an efficient transfer of energy from one circuit to the other, this transfer being continued while electric waves are being radiated, until the energy has all been transferred from the reservoir or persistent oscillator circuit to the antenna or radiator circuit, and thereafter, if the circuits are properly adjusted, the closed circuit ceases entirely to operate while the antenna circuit continues to radiate until its energy has been dissipated.

Current oscillation and energy transfer: Illustrating the oscillation of current in a circuit by a sinuous or wavy line, as I have already done in the case of Waterman sketch No. 1, I illustrate by Waterman sketch No. 2 the oscillation of current in the two circuits of a transmitter, properly adjusted as described in the specification.

On this sketch the upper figure (*a*) illustrates the oscillations of a charge in the primary circuit and the lower figure (*b*) the transfer of the charge to the secondary circuit and a portion of the train of oscillations therein. In these figures the horizontal line *o, x*, indicates the progress of time and the sinusoidal line indicates the oscillations of the charge. At the time *o* there is a maximum charge in the primary circuit and no charge at all in the secondary or antenna circuit. Upon the passage of a spark across the spark gap in the primary circuit the charge begins to oscillate in the circuit and energy is transferred to the primary circuit, building up a charge therein. As soon as the charge begins to flow in the secondary circuit, electric waves begin to be emitted. The oscillation of the charge in the primary circuit continues, however, to transfer energy to the secondary circuit until finally at the time *y*, indicated in the

upper figure, so much of the energy has been transferred to the secondary circuit that the electrical pressure does not rise high enough in the condenser to any longer jump the spark gap. I have indicated by a dotted line *z* in the upper sketch the pressure corresponding to that necessary to cause current to flow across the gap, and since the voltage at the time *y* fails to rise to that necessary the primary circuit ceases to have current oscillating in it.

The current in the secondary circuit, however, continues to osciliate, and there being no spark gap in the antenna circuit to waste energy the oscillation continues until it has been radiated in the form of electric waves. Theoretically this oscillation would go on forever, but practically of course the waves die out, and it is customary to state the number of oscillations taking place as the number which has occurred when the oscillating charge has fallen to 1 per cent of its maximum value. It will be understood that the Waterman sketch No. 2 is merely a free-hand sketch, not drawn to scale, and that it illustrates the whole of the operation of the primary circuit and the most significant part of the oscillations of the secondary circuit.

In this manner, as a result of the resonant relation of the two circuits, energy is first taken in the primary circuit which cannot radiate it, and is transferred from that circuit in the form of resonant oscillations set up in the secondary [fol. 308] circuit. If the circuits are properly adjusted and also properly associated with one another, this transfer takes place as indicated in the sketch No. 2, the antenna circuit gradually taking over the energy from the primary circuit and then radiating it in this space. It will be seen that this corresponds to the description of the specification which I have quoted from page 2, lines 25 to 38, which says in the last sentence:

"If the capacity, inductance, and the resistance of the circuit are of suitable values, the discharge is oscillatory, with the result that only currents of high frequency pass through the primary of the transformer and induce similar oscillations in the secondary, these oscillations being rapidly radiated in the form of electric waves by the elevated conductor."

Degree of coupling or association of circuits: The association, or as it is called at the present time the coupling of

the two circuits, must not be too close if the best results and the precise results indicated in Waterman sketch No. 2 are to be obtained. The desired looseness of association or coupling is obtained in the illustrated arrangement of the patent by using in the secondary of the oscillation transformer *d'* only two turns of wire and only a single turn in the primary circuit. A similar result can be obtained of course by using more turns and increasing the separation between the two circuits.

The transfer of energy from one circuit to the other occurs, as I have explained, as a result of the "cutting" or "threading" of the secondary circuit by magnetic lines of force produced by the other. The closest association of the two circuits which could exist would be the condition in which every line of force produced by either one is so located as to cut the other. It is customary to express the coupling in terms of a percentage and the condition just mentioned where every magnetic effect produced by one circuit was experienced by the other would be stated as 100 per cent coupling. Such a coupling is neither possible nor desirable. It is not possible because many of the magnetic lines of force produced in this circuit must of necessity be produced by portions of the circuits not in proximity to one another, and it is not desirable because a too close association of circuits will result in a retransfer of energy from the antenna back to the primary circuit, thus producing a great waste of energy and also a disturbance of the regular and rapid radiation of waves of which the patent speaks.

The percentage of coupling existing in the transmitter is expressed as the ratio of the number of lines of force actually common to the two circuits to the maximum number possible. This at least is as nearly an accurate statement as can be made in simple terms. In mathematical terms the coupling is equal to the mutual inductance of the two circuits divided by the square root of the product of their self-inductances. Mutual inductance is the effective number of lines of force produced by one circuit, which is linked with the second circuit for each unit of current employed in the first circuit.

In view of this definition of coupling, it is apparent that the coupling or association between the two circuits can be affected by varying either the number of turns in the oscillation transformer or by varying the number of turns in the

coil outside of the oscillation transformer, as for instance the coil *g* in Figure 2 of the Marconi patent. It can, as stated, also be varied by varying the separation of the coils. [fol. 309] All three of these methods are employed in practice in obtaining the most advantageous degree of association of the two circuits.

If the circuits are too closely associated, defects of operation occur as the result of the reaction of the secondary circuit back upon the primary circuit. It will be seen that since two circuits are associated so that energy may be transferred from the nonradiating circuit, to which the charge is initially given, over into the radiating circuit it necessarily follows that the oscillations occurring in the secondary circuit would have a tendency to react and produce oscillations in the primary circuit and thus transfer the energy which the antenna circuit has received back into the primary circuit instead of radiating it. If the association of the two circuits is so close that this tendency to the backward transfer of energy is great enough to cause the spark gap in the primary circuit to be broken down, then energy will be retransferred back to the primary, thus wasting it in the spar gap instead of radiating it as an electric wave.

It is evident that such radiation as takes place in the antenna under such circumstances will be very much less than would take place with a proper association of the circuits; and further, such a retransfer of energy to the primary circuit disturbs the radiation which does occur, so that the circuit behaves as though it were radiating two waves at once instead of only one. Further, neither of these is the correct wave which it should radiate.

It is important, therefore, in order that the efficient radiation to which the patent refers may be secured that the association between the two circuits should not be so close as to permit the secondary circuit to break down the spark gap by reaction upon it. When the association is a proper one the oscillation of the primary circuit will cease, as shown in Waterman sketch No. 2, as soon as the primary circuit has transferred its energy to the secondary and the more quickly this can be done the better, because the smaller will be the energy consumed in the primary circuit itself and the greater will be the amount remaining to be radiated.

It will be observed that the resonant relation between the two circuits, as set forth in the patent, is stated in some-

what mathematical terms—that is, as equality of the products of the capacity and the self-inductance in the two circuits. It must not be understood from this that effective operation requires a rigidly or mathematically exact adjustment of the two circuits, nor that the mathematical statement expresses the way of doing it, for neither of these things is true. No mathematically exact or precise equality between the circuits is realizable in practice, but it is important to the efficient transfer of energy that this equality should be approximately or substantially attained.

Circuit-adjusting means: The specification says, on page 3, line 12:

"The adjustment of the self-inductance and capacity of any or all of the four circuits can be made in any convenient manner and employing various arrangements of apparatus, those shown and described herein being preferred."

Referring to Figure 1 of the patent, or Figure C of plaintiff's Exhibit No. 99, it will be seen that the inductance of the antenna circuit is made variable by the adjustment of [fol. 310] the contact point thereon so as to include in the circuit more or less of the turns of wire constituting that coil. The primary circuit is described as preferably provided with an adjustable condenser whereby the products of capacity and inductance in that circuit may be adjusted. Thus the specification says, page 1, line 88:

"A condenser *e*, preferably one provided with two telescoping metallic tubes, separated by a dielectric and arranged to readily vary the capacity by being slid upon each other, is included in one connection from the induction coil to the transformer-winding *d*."

In practice it is customary to either build or adjust one of the circuits to the desired wave length or frequency of oscillation and then adjust the other to it after the apparatus is set up ready for operation. If it is not desired to change the wave length, no further adjustment is required. If it is desired to sometimes operate at one wave length and sometimes at another, then if good results are to be desired both circuits must be changed to the desired wave length. Sometimes this is done by providing a switch or switches by which, after the initial adjustments for each position of the switching apparatus have been made, changes can be quickly

made from one wave length to another with a certainty that the two circuits are always in resonance with one another.

Illustrative transmitters of the patent: I have called attention to the fact that the specification refers to the use of the inductance coil *g* in the antenna circuit as optional or "for the best results," and that it refers to the complete system as one provided with all of the described adjuncts. By way of illustration of various ways of embodying the invention the specification gives, on page 4, in tabular form various arrangements marked "tune 1," etc., six arrangements being described.

Plaintiff's Exhibit No. 99 gives, in Figures D, E, and F, the several combinations indicated in this table, the indication being, of course, in diagrammatic form. Thus tunes 2 and 4 are illustrated by Figure D, tunes 1, 3, and 5 by Figure E, and tune 6 by Figure F. It will be noted that tunes 2 and 4 employ the inductance coil *g* in the antenna circuit, while tunes 1, 3, 5, and 6 do not. Tunes 1 to 5, inclusive, have an oscillation transformer, having only one turn in its primary and two in its secondary, while tune 6 has a number of turns in both the primary and secondary windings.

Receiving apparatus: Referring now more particularly to Figure 2, the receiving apparatus, there illustrated, shows the complete arrangement with all of the adjuncts and tuning devices necessary for the most complete and perfect realization of the several objects of the invention. On page 4, there is given a table of receiving station arrangements in which the several instrumentalities shown in Figure 2 and described in the specification are combined in various ways and in simpler combination than in the complete apparatus of Figure 2. Most of these variations have to do merely with the presence or absence or completeness of the adjusting means provided for the resonant adjustment of the two circuits.

In Figure 2 the means for collecting energy from the radiated waves as they pass the receiving station is the elevated wire A and capacity area *f'*. For the purpose of getting the desired degree of resistance and also correctly determining the wave length, the coil *g'* is inserted in this circuit. Instead of placing the detector in the antenna circuit as in the arrangement of the prior [fol. 311] Marconi patent No. 11913, referred to in the specification, an oscillation transformer primary coil *j'* is inserted, and as a further means of tuning the circuit, a condenser *h*

whose capacity is variable is employed, if desired. Thus, the specification says, page 2, line 83:

"In a shunt around said primary j' I usually place a condenser h."

This condenser is said to be similar to the condenser e, which is described as adjustable. The word "shunt" used in the above quotation means a by-path, and the application of the term is evident from the drawing.

This condenser h has no important or modifying effect on the general mode of operation, but is merely a means for varying the capacity of the antenna circuit and hence of providing a way of altering or adjusting the wave of length of the circuit to agree with that of a signal to be received.

The secondary or local receiving circuits are arranged in such manner in the drawings as appear to be more complex than they really are, and I therefore have made a sketch illustrating Figure 2 without altering the essential relation of the parts or their mode of operation. In preparing this drawing I have used the same letters of reference as are used in the patent but I have in some instances varied the symbols employed to correspond with more ordinary present-day conventions, particularly as there are already in the record many circuit diagrams which employ these newer conventions.

Referring to the sketch, which I call "Waterman sketch No. 3." Marconi simplified receiving circuit, the antenna circuit, which is shown for the sake of completeness is in no way modified. It comprises the capacity area f, vertical wire A, variable loading coil g', tranformer primary j', variable condenser h, and earth connection E. Associated with the primary of the oscillation transformer is the secondary winding j^3 whose two ends are connected with variable inductances or secondary loading coils g^2. In the figure of the patent this secondary winding is divided in the middle to permit the connection therein of the condenser j^3. This, however, has no essential relation to the mode of operation but is merely a refinement, and I have therefore not shown the parts arranged in that manner in my sketch.

Across the terminals of the secondary and the adjustable inductances g^2 is a variable condenser h', regarding which the specification says page 2, line 109:

"A condenser h' is sometimes included in a shunt around the detector T."

The use of this condenser is therefore not required, but it is employed as a convenient mode of varying the time period or wave length of this local circuit, and thus bringing about the adjustment to resonance, which the specification describes. In any case it is merely an exterior capacity added to the capacity of the secondary circuit itself, and it is employed because such a small condenser can easily have its capacity varied when desired, while only the inductance of a coil can conveniently be altered. Means for altering the inductance in the circuit is shown at g^2.

The terminals of the secondary coil are connected, in this instance through the inductance coil g^2, to the detec-
[fol. 312] tor T, the condenser j^3 being in series therewith, as in Figure 2 of the patent. The purpose of this condenser j^3 is merely to afford a convenient way of associating the indicating device or telegraph instrument I with the circuit without interfering with the oscillations set up therein by the wireless waves. The most advantageous construction of an indicating or telegraph instrument device for such purpose is generally incompatible with good results if it is placed directly in the high-frequency oscillating circuit. It is therefore customary to connect it in the manner shown by Marconi, namely, with a condenser, such as j^2 connected across its terminals. If this condenser is of considerable size, it has very little effect upon the oscillatory currents in the circuit, but it compels the battery current of the local battery to take its proper course through the detector and so permits the indicating device to respond.

It is a curious fact which must be borne in mind in dealing with wireless telegraph circuits that for the purposes of the high-frequency oscillatory currents a large condenser acts almost like a continuous wire, and when placed in a circuit in series or tandem relation with a small condenser it has very little effect.

Around this condenser j^3 is connected the indicating device R, with its local battery B and two small "choking" coils c' c^2. The purpose of these coils is merely to exclude the oscillatory currents from the indicating device. In modern practice these coils are usually omitted because the indicating device itself can just as well be constructed

to exclude the oscillatory currents by giving it a sufficient amount of inductance.

In connection with Figure 2, I call attention to the reproduction thereof in plaintiff's Exhibit No. 99, Figure C, where the antenna circuit is shown in black lines, the path of the oscillatory currents through the secondary circuit is indicated in red, and the local indicating circuit is shown in green. In this arrangement the condenser j^3 is connected into the middle of the secondary coil, but this is entirely immaterial, as it may be put anywhere else in the circuit, so long as it takes with it when it is moved the terminals of the indicating or green circuit.

Operation of receiver: The operation of this complete apparatus is as follows:

When the wireless waves are sent out from a transmitter they pass the receiving station, moving with the speed of light. Being of conducting material the antenna circuit, raised high in the air, is not transparent to the waves, but intercepts that portion of them passing the point where it is located and absorbs the energy of that portion with the result that a charge is communicated to the antenna which oscillates in the form of a current therein. The oscillation of the current through the primary coil j' produces a magnetic field which threads the secondary coil j^2 and sets up therein another current which oscillates by virtue of the inductance and capacity of the secondary circuit. Across this secondary circuit is connected a detector T which, responding in any appropriate way to the electromotive force thus brought to bear upon it, causes the indicator R to act.

Character of detector: As to the particular character of this detector or, as the specification also calls it, "responder," the specification says on page 2, lines 57 to 77:

[fol. 313] "As a responder to electric waves I may use at the receiving station any of the now well-known forms of such devices, such as those which depend for their action on the reduction of the resistance of a metallic microphone by the action of electric waves or 'coherers,' one form of which is disclosed in my patent No. 586193, or I may employ one which depends for its action on the increase of the resistance of the device under the influence of the electric waves or 'anticoherers,' such as described by Branly in

La Lumiere Electrique of June 13, 1891, or I may use those which depend upon the action of an electric wave as a magnetizing or demagnetizing agency, such as I have disclosed in my application, serial No. 132974, filed November 28, 1902, or I may use various other well-known devices, such as the electrolytic, electrothermal, electromagnetic, or electrodynamic responders."

Again, on page 2, lines 106 to 107, the specification refers to the device as "a coherer T or other detector of electrical oscillations."

It is therefore evident that the precise action which takes place in the detector depends upon the particular character of the detector employed. The mode of operation of many of the detectors in common use is not well understood, but most of them appear to operate by reason of some change in their resistance produced as a result of the arrival of the electric waves. Some of these detectors in commercial use require the presence of a local battery B; others may be used either with or without it, and some work better without it.

If the detector employed is a coherer or sensitive tube, just as was most commonly employed at the date of the patent, then the effect of the charge imparted to the secondary circuit and by it to the tube had the effect of lowering the resistance until a sufficient current was able to flow from the battery B to operate the indicator R. If the detector is of the electrolytic or electrothermal type, such as the crystal detector, for instance, then it acts apparently to permit the flow of current in one direction through it but to exclude a flow in the opposite direction. This permits or crosses a variation of current through the indicating device R, if there is a local battery present, or causes the flow of a portion of the current received from the waves through the indicator if there is no local battery present.

Illustrative receivers of patent: As the specification points out, in order to obtain good results it is essential that the received energy should be effectively transferred from the antenna circuit to the secondary circuit, and to produce this result the patent states that the secondary circuit must be placed in resonance with the antenna circuit by the adjustment to the proper value of the products of inductance and capacity in that circuit.

As I have already pointed out, this does not mean the two circuits must have the same inductance and the same capacity, but only that their product should be the same. This makes it possible to construct the two circuits, each to best fulfill the purpose to which it is put and to provide fixed adjustments or variable adjustments as may be most convenient for specific installations.

As illustrating these various ways in which the elements useful in a receiving apparatus may be combined a table is included on page 4 which, taken in connection with the descriptive matter on pages 3 and 4, specifies six illustrative arrangements.

These illustrative arrangements are diagrammatically shown in plaintiff's Exhibit No. 99, Figures G, H, I, and J. [fol. 314] Figure G illustrates the combination of elements specified in the table as to tunes 1, 5, and 6. Examination of Figure G and a comparison with Figure C (or with Figure 2 of the patent), shows that the arrangement of these tunes differ in that the coil g' and condenser h are omitted from the antenna circuit and the condenser h' is omitted from the secondary circuit. Remembering that the condenser j^3 in the secondary circuit is merely a means of connecting the indicating device it will be seen that in this instance the secondary circuit has no condenser at all but the entire capacity utilized in making the circuit resonant to the antenna circuit is the capacity of the devices themselves. It will also be noted as to the arrangement of Figure G that there is omitted from the secondary circuit the adjustable inductance coil g^2 and in fact that in neither of these circuits is there any adjusting device.

This arrangement of tunes 1, 5, and 6 is therefore the simplest possible arrangement of the apparatus which is specified. Such a receiving station arrangement would be used at a station designed always to receive waves of one wave length only and both circuits would be constructed to be of this wave length, the adjustment of the capacity and self-induction for both circuits being made once for all in the setting up of the installation.

Figure H illustrates the arrangement of tune 2. In this arrangement both circuits have adjusting means, that of the antenna circuit being found in the coil g^1 and that of the secondary circuit being the variable condenser h'. The arrangement differs from the complete system shown in Figure 2 in that the variable condenser h is omitted from

the antenna circuit and the variable inductances g^2 from the secondary circuit.

Figure I shows the arrangement specified as to tune 3. In this the primary circuit—that is the antenna circuit—is identical with that of Figure 2, but the secondary circuit has no means of variability since it has neither the inductance coil g^2 nor the variable condenser h'. In this instance the secondary must be constructed to be in tune for a particular wave length by having its parts so constructed as to have the desired capacity and inductance built into them. To efficiently receive some other wave length for which the antenna circuit might be readjusted by the variable adjusting device which it contains another secondary circuit might be substituted or another oscillation transformer and its adjuncts.

Figure J differs from Figure 2 only in that the variable condenser h' is omitted, and differs from Figure I in that the variable inductance coils g^2 are added. In this arrangement, therefore, as in Figure 2 and in Figure 8, both of the two circuits have variable means of adjusting the time periods of the two circuits to resonance with one another.

As to all of these arrangements as well as the arrangement of Figure 2 (the latter showing the receiving station in its most complete form), the description of the specification applies, namely, that the two circuits are so adjusted with reference to one another as to be in electrical resonance, that is to have like products of capacity and inductance.

As in the case of the transmitting apparatus, it should be borne in mind that this adjustment is not a mathematical but a manipulative operation and that it is indeed [fol. 315] very difficult to know precisely what the capacity of either circuit or their inductance of either circuit is in numerical terms. In any case, therefore, the construction or adjustment is made by reference to a known standard or to response to a given wave. Further, this adjustment is not one requiring mathematical precision nor indeed is such precision attainable, but in general substantial attainment of the resonant relation is essential to the best results and the nearer it is attained the better will be the result.

On page 3 the specification gives specific directions for the construction of a number of receiving-station oscillation transformers, descriptions being made in connection with

Figures 5 to 8. The figures show various mechanical arrangements which, I take it, it will not be necessary to consider specifically. I will merely point out, therefore, that in Figure 8 the primary and seconda-y coils are wound upon separate insulating tubes, one of which is arranged to siide into and out of the other for varying the "coupling" or association of the two circuits. This is a mode of construction which has been most commonly employed in practice.

Of the claims referred to in the question, claims 1, 3, 6, 8, 11, and 12 descriptively relate to the transmitting station, claims 2, 13, 14, 16, 17, 18, and 19 to the receiving station, and claims 10 and 20 to both. I here quote these claims in groups as above recited:

Transmitting-station claims:

"1. At a station employed in a wireless-telegraph system, a signaling instrument comprising an induction coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency; an open circuit electrically connected with the oscillation producer aforesaid and a variable inductance included in the open circuit, substantially as and for the purpose described."

"3. At a station employed in a wireless-telegraph system, a signaling instrument comprising an induction coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency, and the primary circuit of which includes a generator; means for varying the primary circuit; an open circuit electrically connected with the oscillation producer aforesaid, and a variable inductance included in the open circuit, substantially as and for the purpose described."

"6. At a transmitting station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to a condenser circuit discharging through a means which automatically causes oscillations of the desired f-equency, and means for adjusting the oscillation period of each of the two circuits connected with the transformer to bring them into accord with each other, substantially as described."

"8. At a transmitting station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, a variable inductance being included in said circuit, and whose primary is connected to a condenser circuit discharging through a means which automatically causes oscillations of the desired frequency, substantially as described."
[fol. 316] "11. In apparatus for communicating electrical signals, the combination with an oscillation transformer, at a transmitting station, of an induction coil; an electric circuit containing the secondary of said coil, a condenser and the primary coil of the oscillation transformer; a producer of electric waves of high frequency electrically connected with the secondary of the induction coil; a signaling instrument in circuit with the primary of the induction coil; the secondary coil of the oscillation transformer electrically connected, at one end to capacity and, at the other end, to an inductance, and an aerial conductor connected to the inductance, substantially as and for the purpose described.

"12. In apparatus for communicating electrical signals, the combination with an oscillation transformer at a transmitting station of an induction coil; an electric circuit containing the secondary of the said coil, a condenser and the primary coil of the oscillation transformer; a producer of electric waves of high frequency connected with the secondary of the induction coil; a signaling instrument in circuit with the primary of the induction coil; the secondary coil of the oscillation transformer electrically connected at one end to capacity and at the other end to a variable inductance, and an aerial conductor connected to the variable inductance, substantially as and for the purpose described."

Receiving-station claims:

"2. At a station employed in a wireless telegraph system, an oscillation-receiving conductor, a variable inductance connected with said conductor, a wave-responsive device electrically connected with said conductor and in circuit with a condenser, substantially as and for the purpose described."

"13. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said

transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a variable inductance being included in said circuit, a wave-responsive device electrically connected with the other winding of the oscillation transformer, and a condenser in circuit with the wave-responsive device, substantially as described.

"14. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation transformer, and means for adjusting the two transformer circuits in electrical resonance with each other, substantially as described."

"16. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, an adjustable condenser in a shunt connected with the open circuit and around said transformer coil, a wave-responsive device electrically connected with the other coil of the oscillation transformer, and means for adjusting the two transformer circuits in electrical resonance with each other, substantially as described.

[fol. 317] "17. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and means included in each of said transformer-circuits, for adjusting said circuits in electrical resonance with each other, substantially as described.

"18. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end, and capacity at the other end, a variable inductance being included in said open circuit, a wave-

responsive device electrically connected with the other winding of the oscillation-transformer, and a variable inductance included in circuit with the wave-responsive device, substantially as described.

"19. In a system of wireless telegraphy, the combination at a receiving-station, of an oscillation-transformer; an open circuit comprising, in part, an aerial conductor connected with one end of the primary coil of the oscillation-transformer; a connection from the other end of said coil to capacity, a variable inductance in said open circuit, and electrical connections from the secondary coil of the oscillation-transformer to a receiving instrument, battery, condenser, wave-responsive device, and a variable inductance, substantially as and for the purpose described."

Claims covering both stations:

"10. A system of wireless telegraphy, in which the transmitting-station and the receiving-station each contains an oscillation transformer, one circuit of which is an open circuit and the other a closed circuit, the two circuits at each station being in electrical resonance with each other and in electrical resonance with the circuits at the other station, substantially as described."

"20. In a system of wireless telegraphy, a transmitting-station containing an oscillation-transformer, the primary of which is connected to a condenser-circuit discharging through a spark-gap which automatically causes electric waves of the desired frequency, the secondary of said transformer connected to an open circuit including a radiating-conductor, and with a capacity and a coil for charging the condenser aforesaid; a receiving-station containing an oscillation-transformer, the primary of which is connected with an oscillation-receiving conductor and with a capacity, a wave-responsive device connected with the secondary of said transformer, and a receiving instrument connected with the wave responsive device, all in combination with means for bringing the four transformer-circuits, two at each station, into electrical resonance with each other, substantially as described."

I have, I believe, already defined the technical terms employed in these claims, and explained the mode and operation of the apparatus described in the specification, and I

assume, therefore, that it will be unnecessary for me to explain the language of the claims in detail.

8. Question. You have used the term "tuning" and also the words "syntony" and "selectivity" with respect to each of the three patents considered in your last preceding [fol. 318] answer, and in respect to the last three patents you have also used the expressions "tuning" and "resonance." To avoid misunderstanding and make more clear the meaning of the several patents and the distinction between the apparatus which they describe, will you please point out the meaning of these terms as employed in connection with the Marconi reissue patent No. 11913, the Lodge patent No. 609154, and the Marconi tuning patent No. 763772?

Answer. In the terminology of the practical art these three patents have been commonly known, respectively, as "the plain antenna patent," referring to reissue patent No. 11913; the Lodge "loading coil patent," corresponding to No. 609154; and "tuning patent" or the "four-circuit tuning patent," corresponding to patent No. 763772. These designations very well illustrate the relation in which the patents stand.

The Marconi patent, No. 11913, disclosed to the world the idea of emitting electric waves from and receiving them by grounded antennae. The antennae consisted of elevated capacity areas having vertical wires connecting them to the transmitting and receiving apparatus, respectively, and thence to the earth. This first Marconi patent directs that the elevated plates or capacity areas are "preferably electrically tuned with each other," and on page 4, line 123, it appears that this preferable tuning is accomplished by making the elevated conductor at the receiving station similar to that of the transmitting station.

The idea of tuning as set forth in this reissue patent was therefore the idea of constructing the receiving station so that it should be identical with the transmitting station, to the end of localizing at the receiver the messages from this particular transmitter. There was involved here only the simple idea of a transmitting and a receiving station, each established to cooperate with the other, and the idea of constructing them to be similar to one another in their physical dimensions was to assist in localizing correspondence between them.

The apparatus of this first patent, while, of course, immensely useful, and particularly with respect to the grounded antenna construction, the foundation of all practical wireless telegraphy, was not particularly successful in respect of localizing messages. This was because the radiator radiated too rapidly to be sufficiently definite in its frequency, and the receiver absorbed too readily, and hence absorbed waves of different length and ferquency from that which was intended.

The Lodge patent, No. 609154, employed the term "syntony" to designate this interstation tuning referred to in the Marconi reissue patent, and provided means of realizing more effectively Marconi's idea of localizing a particular message at the designated receiving station. He also introduced the idea of varying the frequency of oscillation or wave length characteristic of both a sending and receiving station in order that a plurality of stations might selectively operate one with another, thus making the system more flexible, so that a receiving station might receive from any one of a number of transmitting stations and a transmitting station to transmit to any one of a number of receiving stations.

This idea of selective syntony between stations has been designated in the art by the terms "syntony," "selectivity," and "interstation tuning," or, for short, simply "tuning."

[fol. 319] In the early Marconi patent and in the Lodge patent no other use of the idea of resonance is made. They relate exclusively to interstation communication by localizing messages at the desired station. This localizing involves two ideas—first, the idea of avoidance of interference, and, second, that of better reception, as I have already explained.

The Marconi patent No. 763772 also aims at the localization of messages at a selected receiving station, but in addition it introduces the idea of employing at each station both a radiating and a non-radiating circuit and effectively transferring energy by tuning these circuits to resonance. Marconi thereby enabled much more energy to be imparted to the radiator by coupling to the transmitting antenna a reservoir circuit. With such a circuit tuned to substantial resonance with the antenna circuit not only may much more energy be imparted to the radiator, but the radiated waves may be made still more prolonged and definite as

to frequency, and thus this intercircuit tuning becomes also a means of improving the quality of interstation tuning.

At the receiving station also the tuning to resonance of the absorbing antenna circuit and the nonabsorbing and nonradiating local circuit produces a more definite and less damped oscillation of the receiving antenna and a more effective accumulation of the energy from a distant station.

Thus this idea of resonance between local circuits in the Marconi second or tuning patent is an entirely different thing from the interstation tuning, referred to in the first Marconi patent and the Lodge patent, but it is a means which, while increasing the energy and the distance of signaling, possible with antennæ of given dimensions, also improves and facilitates interstation tuning.

In the first Marconi patent and in the Lodge patent there is one circuit at the transmitting station and one circuit at the receiving station tuned to agree with the transmitter. In the arrangement of the second Marconi patent there are two circuits tuned to resonance with one another at the transmitting station and two circuits tuned to one another at the receiving station, these circuits being also tuned to the wave length emitted by the transmitting station.

9. Question. Please compare the construction and mode of operation of the apparatus or elements of each of the radio systems, respectively described by Messrs. Weagant, Graham, and Langley in their depositions herein, and diagrammatically illustrated in plaintiff's Exhibits No. 79, "Drawing, Telefunken apparatus"; No. 87, "Drawing, Wireless Specialty Apparatus"; No. 87a, "Wireless Specialty Apparatus Co. instructions for I-P-76 set"; No. 88, "Drawing, Wireless Improvement Co. Apparatus"; No. 89, "Drawing, Simon apparatus"; No. 93, "Drawing, type of r-dio apparatus manufactured by Navy"; and No. 95, "Drawing, Kilbourne & Clark type of radio apparatus," referred to, respectively, by them in their depositions, with the construction and mode of operation of the radio system and apparatus of the inventions described in the Marconi patent No. 763772, and claimed in claims 1, 2, 3, 6, 8, 10, [fol. 320] 11, 12, 13, 14, 16, 17, 18, 19, and 20, pointing out, in your opinion, the similarities and differences between said systems and apparatus of said patent, as referred to in said claims, and the said systems and apparatus de-

scribed by Messrs. Graham, Langley and Weagant, and illustrated in said exhibits, giving your reasons for any opinion you may express. In making the comparison you may, if you desire, make any sketches or drawings you deem necessary and refer to any other exhibits introduced herein in support of any opinions you may express.

Answer. A comparison of the exhibits referred to in the question, namely, plaintiff's Exhibits Nos. 79, 87, 87a, 88, 89, 93, and 95, and Figures 1 and 2 of the second Marconi patent No. 763772 in suit and Figure C of Exhibit No. 99, which is a colored reproduction thereof, shows them to be substantially alike, the differences being all of minor and unimportant character. In each there is for each station shown a similar combination of similar elements; thus each transmitting station shown in these exhibits comprises a power circuit and operator's key, shown in yellow, a local closed nonradiating oscillatory circuit, consisting of a reservoir condenser *c*, an inductance *d*, and a spark gap G, and each of these closed reservoir circuits has some means, indicated by an arrowhead, for adjusting the time period of oscillation of the circuit. Each transmitting station also has an open radiating circuit, comprising an elevated capacity area *f*, a vertical wire *a*, connected through the transmitter to the earth at E, and each has an inductance coil *d'*, acting also as the secondary in the oscillation transformer. Some of these transmitters also have the separate inductance coil *d* and all have means, indicated by one or more arrowheads, for varying the time period of oscillation of the circuit.

It will perhaps be convenient to select one or two of these exhibits and consider the structure disclosed and then consider the others so far as they differ from the ones selected.

Comparison of apparatus of Marconi patent 763772 and Wireless Specialty Apparatus transmitter.—Referring to plaintiff's Exhibit No. 87, showing the apparatus of the Wireless Specialty Apparatus Co., and comparing the apparatus as described by Mr. Langley, and in several other exhibits pertaining thereto, as for example plaintiff's Exhibit No. 60, Navy contract No. 132, plaintiff's Exhibit No. 62, plaintiff's Exhibit No. 87*a*, the whole apparatus may be clearly understood.

Comparing it with plaintiff's Exhibit No. 99, Figure 6, which is a reproduction in colors of Figures 1 and 2 of

the Marconi patent No. 763772, it will be seen that the yellow, red, and black circuits at the transmitting stations are identical, in that each has a source of current *a*, a key *b*, and a transformer or induction coil *c*. in its yellow circuit. In its red circuit each has a condenser *e*, the primary *d*, of an oscillation transformer, a spark gap G. The sole difference between this red circuit of Exhibit No. 87 and that shown and described in the Marconi patent is that the inductance of the oscillation transformer primary *d* is variable and the condenser fixed, while in the Marconi description the reverse is true, as there the condenser is [fol. 321] variable and the inductance *g* is fixed. Since these are merely the means of adjusting the time period of the circuit in each case, it is clear that the circuits in substance are identical.

Similarly comparing the black circuits of the transmitting station, each has the following elements:

An elevated capacity area *f*, a vertical wire A, a variable inductance coil *g*, a secondary *d'* of an oscillation transformer, and earth connection E. The sole difference is that the number of turns of the oscillation transformer secondary *d'* in Exhibit No. 87 is indicated as variable, while it is not so described in this Marconi's patent, although oscillation transformers having different numbers of turns are described.

In elements, therefore, and in the presence of adjusting means, the transmitter of plaintiff's Exhibit No. 87 is identical with that of the Marconi patent No. 763772. That they are also identical in the adjustment of the two circuits to resonance, appears from plaintiff's Exhibit No. 60, for example, being Wireless Specialty Apparatus Co. Navy contract of September 21, 1912, in which I find the following:

"Wireless Specialty Apparatus Co. proposes to furnish apparatus as per the following details: * * * transmitting inductances will be supplied giving continuously variable wave lengths of 600 to 2,000 meters with no switches, exciting and radiating circuits, always in resonance and with maximum coupling."

Thus it appears that in addition to having the elements of this Marconi patent the circuits are particularly speci-

fied as being "always in resonance," as described in the specification of the Marconi patent. Again on the same point the witness Langley, in his reply to Q. 12, and referring to the transmitter of the Wireless Specialty Apparatus Co. says (MS. p. 190):

"The chief feature of the apparatus in question was this wave length changing switch and the means by which the proper tuning of the several wave lengths in the primary and secondary circuits could be accomplished."

Then in cross-examination, he was asked to state what he meant by tuning and stated in answer to X Q. 88 (MS. p. 221):

"The process of adjusting the closed circuit so that it will have the definite desired frequency and of adjusting the open or radiating circuit so that it will have independent of the closed circuit the same frequency."

Thus it is evident that this Wireless Specialty Apparatus transmitter of Exhibit No. 87 is subsequently identical with that of the Marconi patent, both in construction and mode of operation.

I may note that as regards the spark gap the contract, Exhibit No. 60, says:

"Quenched spark gap, new design, perfect cooling by special central draft. (We reserve right to furnish our new type tubular gap.) This latter having new feature of cooling and perfect sparking alignment with ease of dismantling)."

This emphasizes the cooling and hence the perfect operation of the spark gap indicating its ability to operate in the same manner as the apparatus described in Marconi patent whereby the efficiency of the apparatus is high and the amount of energy imparted to the radiator large.

[fol. 322] Comparing the receiving station type I-P-76 apparatus of Exhibit No. 87 with the colored diagram of Figure 2 of this Marconi patent, as found in Exhibit No. 99, each has an open oscillating antenna circuit, shown in black, a closed oscillating secondary circuit, shown in red, and a local indicating circuit shown in green. In each case, the open oscillating circuit has the following elements:

An elevated capacity area *f*, vertical wire A, a variable inductance coil *d′*, oscillation transformer primary *j′* and earth connections E. This Marconi patent also shows a condenser *h*, in the black circuit of Figure 2, which the Wireless Specialty Apparatus receiver does not have, it being in this respect like the antenna circuit set forth as to tunes 2 and 4 on page 4 of this Marconi patent. I have already called attention to the fact that the specification points out that the condenser *h* is not always used.

The secondary circuits of Exhibit No. 87 and Figure C of Exhibit No. 99 (Marconi patent, fig. 2) each contains the following elements:

Secondary j^2 of an oscillation transformer, variable condenser *h′*, detector T, "blocking" or "stopping" condenser j^3, and the green circuit connected around this condenser. The only difference between the two is that Figure 2 of this Marconi patent has the inductance of the circuit variable by the inclusion of variable inductance coils g^2, whereas in the receiver of Exhibit No. 87 the variable inductance is included in the secondary of the oscillation transformer j^2, as indicated at 7. This is a mere matter of detail, having to do with the mechanical method of associating the two circuits. If the two circuits *j′* and j^2 are made movable with respect to one another to vary the coupling in the circuits, then the same result exactly is obtained as though a fixed secondary were employed and exterior variable inductances g^2 used to vary the inductance.

The green circuits of the two receivers each contain local battery B and an indicating device R. This Marconi patent shows, in addition, in the green circuit choke coils c^1, c^2. These are not shown in Exhibit No. 87, it being customary to incorporate all of the choking effect necessary in the indicating device R itself. Exhibit No. 87 shows the variable resistance device P, often referred to as a "potentiometer." Its purpose is merely to give a more delicate adjustment to the amount of current flowing in the local circuit.

As to the adjustment of this receiver of Exhibit No. 87, it is evident that it has all of the adjusting means set forth in the Marconi patent for putting the two circuits in resonance. I find that the contract Exhibit No. 60 refers to

these receivers as "type I-P-76," and I find that Exhibit No. 87a is a pamphlet issued by the Wireless Specialty Apparatus Co. called "Instructions for I-P-76 set." On page 2 of this exhibit I find the following:

"The aerial, or antenna, is connected to A, and the circuit therefrom, after passing the variable inductance B and the transformer primary I J, is grounded at G. This circuit, which is called the primary circuit, is tuned or made resonant to any desired wave length by variation of either the loading inductance B, the primary I J, or by variations of both. The greater the number of turns of wire included in the primary circuit the greater is the inductance and hence the longer the wave length with which the circuit is in tune.

"Inductively coupled to the primary circuit is the secondary circuit H, including variable air condenser F. [fol. 323] This secondary circuit is tuned to the primary circuit either by variation in the length of the secondary winding or by variation of the capacity of condenser F. While it is possible to adjust the primary circuit by single turns, the secondary winding is made adjustable only by relatively large steps, so that for accurate tuning the condenser F must be used."

Again on page 10 it is stated:

"After the primary circuit has been tuned, the secondary circuit should be brought into resonance. This is accomplished by varying the number of turns in the secondary winding and the capacity of the variable air condenser F."

Other statements of like import might be quoted. Thus it is evident that this receiving apparatus has the two circuits tuned to resonance with one another by suitable adjustments of capacity and inductance.

Also it is evident from the quotations from this Exhibit No. 87a that the whole system consisting of two transmitting and two secondary circuits are in resonance with one another for the first of the above quotations particularly specifies tuning of the antenna circuit of the receiving station to the wave radiated by the transmitting station. Thus all four circuits are in tune, that is, in resonance, the circuits of the transmitting and receiving station respectively being likewise in resonance with one another.

I am personally very familiar with transmitters and receivers, such as are diagrammatically indicated in Exhibit No. 87 and have operated apparatus having identical elements arranged in the same manner, provided with the same adjustments and having circuits tuned to resonance in the same manner. I have also seen a transmitter manufactured by the Wireless Specialty Apparatus Co., although not one sold to the United States Government. I have seen and examined the Wireless Specialty Apparatus Co.'s I–P–76 receiver, which formed a part of the wireless telegraph apparatus exhibit by the Government at one of the electrical exhibitions in New York City and saw it operated by the operator in charge. I may say that I have owned and operated for a number of years transmitting and receiving apparatus, substantially identical with this Wireless Specialty Apparatus type shown in Exhibit No. 87.

From an examination of plaintiff's Exhibit No. 62, contract No. 170, dated April 14, 1912, and plaintiff's Exhibit No. 63, contract No. 19882, dated November 18, 1913, between the Navy Department and the Wireless Specialty Apparatus Co., as well as the exhibits heretofore mentioned, I understand that the apparatus called for in each of these contracts, is substantially the same in construction and mode of operation as already described above.

The details of the construction and mode of operation of this wireless telegraph apparatus of the Wireless Specialty Apparatus Co. are set forth in the deposition of Mr. Langley and as I have pointed out the elements and mode of adjustment and association of the several elements is substantially that specified in this Marconi patent.

Navy wireless specificat ons No. 16–T–5.—I however call attention in addition to plaintiff's Exhibit No 37, Navy wireless specification No. 16–T–5, which is referred to in plaintiff's Exhibit No. 60, contract No. 133, under this contract the apparatus of the Wireless Specialty Apparatus [fol. 324] Co was required to be in accordance with the specification except as modified in the contract. The specifications confirm the statements of the contract with respect to the resonance between the several circuits and confirm my opinion as to the essent al likeness of the apparatus furnished under this contrac with that of the Marconi patent, both in construction and mode of operation.

I call attention to the following quotations from this specification No. 16-T-5; from page 1:

"2. *Aerial* (furnished and installed by the Government.) —(*a*) The contractor shall specify in his bid such special requirements, if any, as to the constants and mechanical construction of the aerial, that it may insure the most efficient operation of the appliances under contract."

The term "aerial" is synonymous with antenna. This clause of the specification therefore shows that the Wireless Specialty Apparatus Co. was required to conform its apparatus to the antenna furnished by the Government and to furnish instructions to the Government as to the specific "constants" (i. e., capacity and inductance) and mechanical construction that it should have to go with the wireless telegraph apparatus to be furnished.

Page 2, under the heading "General design of the transmitter," paragraph 6 (*c*):

"(*c*) Constructions in which the exciting and radiating circuits can be simultaneously and rapidly altered in wave lengths over the entire available range for military purposes without alteration of syntony between the circuits or loss in power are preferred."

On page 3, paragraphs 7 (*h*, *i*, *j*), under the heading "The closed and open oscillating circuit of the transmitter, general":

"(*h*) The contractor shall furnish means by which the transmitting wave lengths can be quickly and easily changed, the apparatus to be permanently marked so that the transmitting wave lengths are known without recourse to diagrams or tables.

"(*i*) Facility for rapid changes is required for military purposes,

"(*j*) The apparatus shall be so constructed that the closed and open circuits of the transmitter can be easily adjusted to syntony for any wave length within the range of the apparatus."

On page 5, paragraph 12 (*a*, *f*), under the heading "Oscillation transformer and antenna helix":

"(*a*) The oscillation transformer shall consist of two inductively coupled coils with means for variation of coupling over a wide range. This range should include an indi-

cator and easily made adjustment for close coupling. The contract shall state the recommended normal degree of coupling and this shall be such as will give only one frequency in the antenna, the change of coupling to be made preferably by mechanical movement of one coil with relation to the other.

"(*f*) Preference will be given to designs embodying:

"(1) Means for continuous variation of inductance and consequent change of wave length by mechanical or other control at a distance, thereby eliminating the necessity for direct manual operation of the individual contact.

"(2) Means for variation of coupling by mechanical or other control at a distance."

[fol. 325] The oscillation transformer will be recognized as the part referred to in this Marconi patent and indicated in Figure 1 at *d, d'*. It is required in the above clauses to consist of two coils, just as in the Marconi patent. The preferred means of variation of the coupling or association between the primary and secondary coil is stated to be the mechanical movement of one relative to the other. I have explained in the foregoing answer that there are various modes of effecting a variation in coupling.

The "antenna helix," referred to above, is the Lodge coil, or loading coil, indicated at *g* of Figure 1 of this Marconi patent.

On page 5, paragraph 13 (*a*), under the heading "Spark gap":

"(*a*) The spark gap to be of approved design and to be adapted for reliable results in the frequent service incident to the work of the station."

Various forms of mechanical construction have been employed in making spark gaps, all aiming to get the best operation, namely, efficient transfer of the energy to the antenna circuit and then complete cessation of action. As briefly stating the facts in this regard I here quote from the Navy Manual of Wireless Telegraph of 1911, page 104, portions of paragraphs 152 and 153:

"152. A great deal of thought and ingenuity has been expended on improving the action of spark gaps. For instance, the use of magnetic blowouts induced and forced air

drafts across the gap; dividing them into a series of short gaps; placing gaps in parallel; inclosing them in compressed air and in nitrogen gas; making the points hollow and cooling them with air or water.

• • • • • • •

"The types of spark gaps now in use are shown in figures 52–61. The only types now supplied are figure 52, the synchronous rotating gap, and figure 57, quenched gap.

"153. The function of the spark gap in an oscillatory circuit is to allow the condenser to charge to the required potential and then to break down and permit the charge to surge back and forth until its energy is dissipated. The ideal spark gap would be one which would insulate perfectly while the condenser was charging and conduct perfectly while it was discharging, and the nearer these conditions can be fulfilled the more efficiently will the spark gap perform its duty. Either condition can be fulfilled alone, but the combination is somewhat difficult to obtain."

On page 9 of 16–T–5, paragraphs 21 (*b*, *c*), under the heading of "Wave lengths of transmitter":

"(*b*) The standard wave lengths shall be 425, 600, and 1,000 meters.

"(*c*) The radiation of each wave length to be practically equal."

This requirement that the radiation shall be equal no matter which wave length is used means that the circuits of the transmitter are to be in syntony or resonance with each other for each one of the required wave lengths, as is provided for in the quotations above rom pages 2, 3, and 5.

On page 9, paragraphs 25 (*a*, *b*, *e*, and *g*), under the heading "Receiver, general design":

"(*a*) The receiving system shall be of the inductive type with suitable provision for a wide range of variation in coupling.

[fol. 326] "(*b*) The range of adjustment for wave length shall be from 200 to 4,000 meters.

"(*e*) Means shall be provided for broadening the tuning of the receiver for the purpose of picking up signals over a wide range with minimum variation of the circuits and for

receiving strongly damped signals to best advantage. A method involving direct coupling will be considered in this connection.

"(*g*) Receiving system wherein the individual circuits may be placed in resonance as a unit with each other and with the incoming signals by the manual operation of a single mechanical element will be given preference."

This requirement for an "inductive type" receiver designates the particular type diagrammatically indicated in figure 2 of this Marconi patent, various forms thereof being indicated in figures 6, 7, and 8. The requirement for a "wide range for variation in coupling" implies some means of varying the association, as, for example, by the use of additional coils such as g^2, shown in figure 2, or by use of the construction, such as shown in figure 8, where the two coils are wound upon separate tubes, one slidable with reference to the other. The reference to "broadening the tuning" refers to the use of some means for permitting fairly efficient reception over a considerable range of wave length for which the receiver would be in approximate but not absolutely exact resonance. For example, the secondary circuit arrangement shown in Figure G of plaintiff's Exhibit No. 99, being the arrangement of tunes 1, 5, and 6 of the table on page 4 of this Marconi patent, is a circuit arrangement suited for this purpose, particularly when the receiving circuits are fairly closely coupled, as when the coils are of considerable size and in close association, as, for example, an arrangement such as figure 6 of the Marconi patent.

It will be noted both as to the transmitter and the receiver that the specification No. 16–T–5, particularly insists upon resonance between the two circuits and expresses a preference for a means whereby in changing from one wave length to another the circuits are automatically preserved in the resonance relation.

I find that the specifications attached to the contract, plaintiff's Exhibit No. 60, do not in any way modify these requirements; on the contrary, I have already quoted therefrom portions referring to the resonance of the circuits. The two are therefore in this respect in accord and cumulative.

The wireless-telegraph system of the Wireless Specialty Apparatus Co., as illustrated and described in the exhibits

referred to and in Mr. Langley's deposition, therefore substantially corresponds in elements, arrangement of circuits, and mode of operation to what is described in this Marconi patent and called for by the claims thereof recited in Q. 9. When installed and operated as the exhibits indicate was intended, this transmitting and receiving apparatus of the Wireless Specialty Apparatus Co. would derive its utility and operative efficiency in a large measure by reason of the constitution, arrangement, and adjustment of the two circuits at the transmitting station, and the two circuits at the receiving station, as set forth in the exhibits and testimony, which, as I have just noted, is the arrangement described and referred to in the claims in issue of this Marconi patent, [fols. 327-328] whereby the two circuits at each station are substantially tuned to resonance with one another—that is, to have the same time period—for, as previously stated, it is by virtue of this arrangement that more energy is imparted to the radiating antenna, that more prolonged and definite waves are radiated therefrom, and a more effective and selective accumulation of energy secured at the receiving station, and consequently a better transmission and reception of signals. The significance of the resonant or equal time period relation is fully recognized in the Government publications in evidence. For example, in the so-called Navy manual for 1913, plaintiff's Exhibit No. 78, on page 57, I find the following:

"89. In Figure 29a, A B and C D have been given some turns in common, forming an air core-auto-transformer, but, whether directly or inductively connected, these two circuits—the closed and open circuits—must have equal natural periods in order to produce and radiate electric waves efficiently."

Again, on pages 162 and 163, I find the following under the heading "Adjustments":

"This includes calibration and tuning. A station is tuned when both sending and receiving circuits are correctly calibrated, coupled, and adjusted to the standard damping and standard wave length.

* * * * * * *

"The closed sending circuit should be in resonance with the open circuit and the coupling and decrement of the

open circuit, such as to afford the necessary selectivity to the receiving circuit with the best efficiency of radiation.

"Receiving circuits to receive from such a sender should be in resonance with each other and with the sending circuits, and should have the same coupling as the sending circuits.

* * * * * * *

"Resonance is thus seen to be a vital quality in wireless-telegraph circuit. * * * (3) Resonance of closed oscillating circuit with open radiating circuit. (4) Resonance of coupled receiving circuits with each other and with coupled sending circuits."

Again, the Signal Corps book, "Radiotelegraphy," plaintiff's Exhibit No. 91, says on page 67:

"When the adjustments of a quenched spark transmitter have been correctly made—that is, the circuits are in resonance, the coupling is right, etc.—a simple experiment will show that the primary current is a minimum; that is, the spark has been quenched and the primary current has been stopped quickly, as at the point Q of Figure 53, and that at the same time the secondary current is a maximum; that is, it persists for a long time, as shown in Figure 56."

Again, at page 107:

"The tuning of the closed and open circuits to resonance and the determination of the correct coupling between them are the two most important adjustments in a quenched spark transmitter."

The expression, "decrement," used in some of the above quotations has reference to the rate of decay of the charge, and hence to the number of effective oscillations.

* * * * * * *

[fol. 329] *General operation of Wireless Specialty Apparatus.*—In using this Wireless Specialty Apparatus transmitter, the apparatus would be put in the desired position and the connections made as shown in the diagram. The first operation would be to make the necessary adjustments to insure the correct wave length and resonance between the two circuits in order to get an efficient transfer of energy. After starting and properly connecting the gen-

erator A the operator or installing engineer would press the key *b* by imparting a charge to the condenser *c* and setting up an oscillatory current in the red circuit by reason of the passage of a spark across the spark gap. By means of a suitable measuring instrument, he would then ascertain whether the product of capacity and inductance in the circuit was such as to give the desired time period or wave length and he would adjust the contact 3 until the correct time period was obtained. He would then proceed to adjust the black circuit, and the most convenient way of doing this is by means of a measuring instrument connected into the antenna circuit or otherwise associated with it, which will indicate the amount of current flowing in the circuit. By varying the contacts 1 and 2, it will be found that when the two circuits are in resonance a maximum current is flowing in the antenna circuit, this being an indication of a high efficiency resulting therefrom. In adjusting the contacts 1 and 2 the contact 2 would be so adjusted as to provide the proper coupling between the circuits and thereafter the contact 1 would be adjusted to give the correct wave length. In designing the antenna structure in the first instance this structure is designed with reference to the wave length or range of wave lengths for which it is to be used, and it is so designed as to require a suitable amount of inductance *g*, so as to give the desired number of waves for each charge imparted to the antanna. Thus this coil *g* is made to serve both the purposes of the Lodge coil, namely, to fix the wave length and establish a definite desired length of wave train. Once these adjustments are made, they need never be altered unless it is desired to transmit at some other wave length, and in this case the adjustments and operations are repeated for the new wave length.

It appears from the testimony of Mr. Langley that a wave-changing switch is provided with the apparatus whereby [fol. 330] by merely throwing this switch into one or another of several positions any one of several wave lengths may be used. In installing the apparatus, the installing engireer makes the adjustments as just described and permanently connects the ascertained points of contacts 1, 2, 3 to this switch, so that with the switch handle in a given position all of these contacts may be correctly made and the circuits will be in resonance. He then makes the ad-

justments in a similar manner for the second one of the desired wave lengths and connects the points 1, 2, 3 so ascertained to another set of contacts upon the switch. This is repeated for the several positions provided for in the specification No. 16-T-5, as for example 425, 600, and 1,000 meters. Thereafter all that the operator has to do is to actuate this switch to the position of the desired wave length and the circuits will be in resonance and the desired wave length secured with maximum efficiency. This is guaranteed in the contract, Exhibit No. 60, as already quoted.

The telegraph operator in using the apparatus therefore merely has to throw his switch to the desired wave length and press the key *b*. Thereupon a charge is imparted to the condenser, and when the condenser is fully charged a spark occurs at the spark gap, thereby setting the charge in oscillation. By virtue of the magnetic field thereby set up in the oscillation transformer energy is thereby transferred to the coil *d'* and a charge is thus imparted to the elevated conductor *f* of the antenna circuit, and because the circuits are in resonance this occurs in an efficient manner and a high voltage is developed in the antenna circuit. The charge thereupon oscillates between the elevated capacity area and the earth, setting up an oscillating electrostatic field and causing electric waves to be efficiently radiated. Because of the red or reservoir circuit a very much larger charge can be imparted than would otherwise be possible, and because of the resonant relation this charge is efficiently transferred and very intense electric waves are radiated. Thus all the benefits of the Marconi patent No. 763772 are secured. By the use of the Lodge loading coil *g* these waves are made more sustained and definite in frequency and exact determination of the wave length is effected, thus securing the benefits of the Lodge invention set forth in patent No. 609154. The antenna circuit is connected to earth, and thus the especially effective radiation of electric waves discovered by Marconi and set forth in his reissue patent No. 11913 result.

For the foregoing reasons I find combined in this Wireless Specialty Apparatus Co. transmitter the disclosures of the three patents just enumerated, the benefits of each being secured in full measure.

In using the Wireless Specialty Apparatus Co. receiver the connections to the antenna and earth constitute the only necessary acts of installation, as the receiver is com-

plete in itself. To receive a message the indicating device R, which in this instance is usually a telephone, is connected and the detector T suitably adjusted by manipulating the contact. The red circuit is then adjusted by moving the contact 7 and, if desired, also making use of the condenser h'. The mode of making the settings, or rather the position in which the adjustable devices are placed, are set forth in the instruction book, Exhibit No. 87a, with sufficient accuracy for a first approximation to any desired wave length [fol. 331] to be received. If it is desired that the operator should also be able to directly set the adjustments 4, 5, 6 of the antenna circuit to approximately the correct points for resonance, then it is necessary that the installing engineer should ascertain by means of a wave meter just what settings are required for a considerable number of wave lengths covering the range of the instrument when connected to that particular antenna and provide a table containing these ascertained adjustments for the use of the operator. The operator can then place the points 4, 5, and 6, as indicated by the table, for the desired wave length and proceed to listen for the desired signal. In doing this he will usually place the secondary coil j^2 of the oscillation transformer within or close to the primary coil j'. When he hears the signal he may alter the adjustments to suit his purpose, first, by getting more accurate adjustment to resonance between the two circuits, which will give him a louder signal; second, by selecting some other combination of adjustments, either for the purpose of getting a still louder signal or for the purpose of receiving with a higher degree of selectivity—that is, more effectively excluding other signals, should any others be heard. He may also adjust the coupling, as, for instance, by moving the secondary of the oscillation transformer, if he desires a still higher degree of selective reception.

As Exhibit No. 87a points out, various specific adjustments may be made to obtain any particular time period or wave length so that the operator may, for example, use a larger part of the winding j^2 and use little or none of the capacity of the condenser h' (the capacity of the coil itself being then relied upon), or he may use less of the winding of the secondary and more of the capacity of the condenser. The instruction book, Exhibit 87a, states on page 12:

"It will be seen from inspection of this table that most wave lengths can be tuned in by several different combinations of secondary windings and condenser capacity."

Examples are then given, and the instruction continues:

"In general the loudest signals are obtained with the longest possible secondary winding and the smallest condenser giving the desired wave length. The sharpest tuning, on the contrary, is usually obtained by using a shorter secondary and a larger capacity, for the reason that the detector circuit, which is practically the only source of energy for the secondary circuit, is connected in shunt therewith.

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"For listening in, or receiving in the absence of interference, it is advisable to use the longest secondary and the smallest capacity that will give the desired tune, together with a fairly tight coupling; that is to say, the secondary should be well to the left and partly inside of the primary winding. In the event of interference, these conditions should be reversed, and a short secondary and a large capacity should be used, together with as loose a coupling as possible, the secondary being well outside the primary, to the right."

By such means the operator is enabled to suit the adjustment to his needs, obtaining the degree of loudness of signal and of sharpness of tuning or selectivity.

What happens in the receiver is that electric waves impinging upon the antena or black circuit of Exhibit No. 87 impart a charge thereto which oscillates between the elevated capacity area and the earth. This oscillation of the [fol. 332] charge produces an oscillating magnetic field by means of which the energy is transferred to the secondary or red circuit, creating an oscillating charge therein the characteristics of which depend upon how the adjustments have been made. If the two circuits are in resonance, as provided in the instruction book, Exhibit 87a, this transfer of energy will be very efficiently accomplished and the operator may determine the required degree of loudness of signal and selectivity to suit himself.

The oscillating charge causes a voltage or difference in potential to exist across the terminals of the condenser k' and the terminals of the coil, acting also as a condenser, and this voltage is impressed upon the parallel branch containing the detector T and stopping condenser j^3, the latter being so proportioned that the oscillating energy may freely pass through it. The detector T then functions, according to the particular method of the detector in use, the details of this action being, as I have said, not fully understood as to any detectors employed in practical wireless telegraphy. In the case of the crystal detectors, furnished under the contract, this action is understood to be such a variation of resistance as permits more current to flow in one direction than in the other. The effect of this is to stimulate a charge in the condenser j^3, thereby varying the current in the battery B through the indicating device R. As I have stated, the potentiometer P is merely a means of adjusting the battery current to the value at which the detector T is most sensitive or gives the best results for the purpose in hand.

Thus this receiver obtains all of the advantages of the Marconi patent No. 763772.

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For the foregoing reasons I find combined in this apparatus of the Wireless Specialty Apparatus Co. the construction and mode of operation disclosed in these three patents and referred to in the claims in issue and the utilization of the benefits resulting therefrom.

Comparison of Telefunken apparatus with Marconi and Lodge patents in suit.—This apparatus is referred to in the testimony of Mr. Graham and shown in the diagram, plaintiff's Exhibit No. 79, produced by him. It is also a subject of plaintiff's Exhibit 46. I may say that I am personally familiar with Telefunken apparatus and have seen it used and used it myself. I understand the testimony and exhibits referring to it.

This Telefunken apparatus, as to the transmitter and as to the Type E^5 receiver in construction and mode of operation, is substantially identical with that of the Wireless [fol. 333] Specialty Apparatus Co. just fully considered. The only difference in the transmitter is in the particular form of oscillation transformer used and the only difference in the receiver E^5 is that it has in addition to the

elements of the Wireless Specialty Apparatus Co.'s receiver the primary condenser *h*, which is shown in Figure 2 of the Marconi patent No. 763772.

Referring to the transmitter, as shown in Exhibit No. 79, the elevated capacity area *f*, vertical wire A, inductance coil *g*, and earth connection E are all as shown in Figure 2 of the patent and as in the Wireless Apparatus Co. transmitter. The oscillation transformer *d*, *d'*, is different from that employed by the Wireless Specialty Apparatus Co. only in that it is of the single coil or "autotransformer" form. When such a transformer is employed the two circuits, red and black, are said to be "direct coupled" and when the two-coil transformer is employed they are said to be "inductively coupled." The only difference between the two transmitters, therefore, is that the Telefunken transmitter is direct coupled and the Wireless Specialty Apparatus Co. transmitter is inductively coupled.

These two forms of transformers are well-known equivalents and merely specifically different ways of associating windings for the transfer of energy. This is so clearly set forth in the U. S. Signal Corps book, Radiotelegraphy, plaintiff's Exhibit No. 91, that I quote the following from pages 42 and 43 and reproduce the Figures 36 and 37 referred to:

"Coupling: By means of the arrangement shown in Figure 36 a large charge may be stored in the condenser C, much larger than that which can be stored in the antenna of Figure 35, and the discharge of this condenser through the gap S and the inductance L will produce powerful oscillations in the closed oscillating or primary circuit. On account of its position and shape, however, this closed oscillating circuit is a poor radiator of electrical energy. There are two general ways in which the energy of this circuit can be transferred to the antenna or radiating circuit; or, as it is said, two ways of coupling the circuits. One is shown in Figure 37, where the ground and the antenna circuits are shown to be directly connected to the inductance coil of the closed circuit, and the circuits are said to be directly connected, directly coupled, or conductively coupled. The coil is often called the antenna coil or helix. The other is shown in Figure 36, where a number of turns in the coil L_2, connected between the antenna and ground, is brought near enough to a number of turns of the

coil L_1 in the closed oscillating circuit to have oscillations induced in the antenna coil and circuit, and the circuits are said to be inductively coupled or connected. The two coils L_1 and L_2 form an oscillation transformer, as it is usually called, the coil L_1 being the primary and coil L_2 the secondary. Hence the antenna circuit is sometimes called the secondary circuit. There is no essential difference in the operation or efficiency of the transfer of energy in the two types of coupling, but rather that each may have advantages in certain cases.''

There is thus no difference in principle or operation between these forms of oscillation transformer, and hence the Telefunken transmitter is substantially identical with [fol. 334] that of the Wireless Specialty Apparatus Co., and what I have said may be taken as applying also to the Telefunken transmitter.

Referring to Exhibit No. 79, the red circuit is the reservoir circuit, and it contains the condenser *e*, spark gap G, and a portion of transformer turns, indicated by red lines between contacts 2 and 2^a. This winding, marked *d*, constitutes the primary of the oscillation transformer. The secondary of the oscillation transformer is comprised by the turns between the connection points 1^a and 2^a and is contained in the antenna or black circuit. The mode of operation is precisely as already described with reference to the Marconi patent Figure 1 and with reference to the Wireless Specialty Apparatus Co. transmitter.

In the drawing, plaintiff's Exhibit No. 79, a switch S is shown in the antenna circuit, so that when desired a condenser H may be included in the antenna. This is merely an additional wave length or time period adjusting device and is only used for the purpose of shortening the wave length below that which is natural to the antenna. Its effect is equivalent to reducing the size of the elevated capacity area. The international convention and the United States laws in conformity therewith require that it shall be possible for ships and land stations licensed for commercial use to send, when required, with a wave length as short as 300 meters. Some antennae are so large as to make this impossible without some means of effectively reducing their size, and this condenser H is supplied for this purpose. Whether it is used or not it in no way affects the mode of operation of the apparatus.

Referring to the Telefunken receiving apparatus, two arrangements of secondary circuits are shown in Exhibit No. 79. One of these marked E^5 is exactly like the wireless specialty apparatus receiver, except for the added condenser *h*, and is exactly like Figure 2 of the Marconi patent No. 763772 in suit, and the other marked E^4 is exactly like the arrangement of tune 3 of the table on page 4 of this Marconi patent, which is illustrated in Figure I of plaintiff's Exhibit 99. It differs from that of Marconi's Figure 2 and of the Telefunken E^5 receiver only in the omission of condenser *h'*. This means merely that capacity enough is provided in the coil itself, the coil referred to being the coil j^2 of the oscillation transformer. In the figure of exhibit No. 79 a variable condenser *h* is shown in dotted lines in the antenna circuit. This means that the condenser *h* is arranged with a switch so that it may be changed from the connection shown in solid lines to that shown in dotted lines. When the condenser is in one position it gives a longer wave length or time period and when in the position indicated by dotted lines, a shorter wave than that natural to the aerial. By this means resonance may be secured between the circuits for a very wide range of wave length.

It appears from the contract, Exhibit No. 46, that the detector supplied with the Telefunken receiver is "iron pyrites." This is another crystal detector, in which one contact is a crystal of iron pyrites and the other a fine pointed wire, adjusted to make a very light contact with the crystal surface. Its operation is supposed to be the same as those which I have considered in connection with the Wireless Apparatus Co. receiver. The indicating device R is a telephone

[fol. 335] In operation the adjustments are made exactly as described with reference to the Marconi patent and the Wireless Specialty Apparatus Co. apparatus, both transmitting and receiving. In the type E^4 receiver there is no secondary condenser *h'*, and hence the entire adjustment is affected by the variation of the inductance contact 4 and by the variation of the detector T. I have personally used this received and have found that change in the adjustment of the detector changes the wave length, the detector acting to cause this result by virtue of its capacity. By the adjustment of these two elements substantial resonance between the primary and secondary circuits is secured.

I observe that the contract, Exhibit No. 46, states that the sets covered by the bid are not in accordance with specification No. 16-T-5. A drawing, however, accompanies the bid showing the transmitting apparatus in detail, and I find that this drawing is correctly indicated diagrammatically in plaintiff's Exhibit No. 79. I am also personally familiar with the Telefunken apparatus, both sending and receiving, and have tested the same and find that the circuits are substantially in exact resonance when adjusted for most efficient operation.

Since this apparatus is exactly like that of the Wireless Specialty Apparatus Co., with the exceptions noted, I will not repeat what I have said in describing that apparatus. In my opinion this Telefunken apparatus embodies the constructions and mode of operation and obtains the advantages set forth in the claims of the Marconi patent referred to in the question.

Comparison of Kilbourne & Clark apparatus with Marconi patent in suit.—The Kilbourne & Clark apparatus is diagrammatically illustrated in plaintiff's Exhibit No. 95, and described in the testimony of Mr. Weagant. It is also the subject of plaintiff's Exhibit No. 69, contract of January 31, 1914, from which it appears that it is in accord with Navy Department specifications No. 16-R-1, plaintiff's Exhibit No. 38, except as provided in the contract.

This apparatus is substantially identical with that of the Wireless Specialty Apparatus Co., the sole exceptions being as follows:

In the reservoir circuit of the transmitter there is in addition to the inductance coil *d*, constituting the primary of the oscillation transformer, a second variable inductance d'', thereby permitting variation of the time period of the primary circuit in two ways, namely, by moving the contact point 3 or by moving the contact point 4.

In the receiver the only difference is that the condenser *h* is provided, as shown in Figure 2 of the Marconi patent, and this is arranged by means of a switch so that it may be either connected as shown in solid lines in Exhibit No. 95 or as shown in dotted lines, so as to either afford means for lengthening or for shortening the wave length of the antenna.

Both these differences are merely additional means of tuning the circuits, giving greater flexibility. They do not alter the mode of operation in any way, and everything

which I have said in comparing the Wireless Specialty Ap-
[fol. 336] paratus Co. transmitters and receivers and their operation with the Marconi and Lodge patents and claims thereof in suit applies equally to the Kilbourne & Clark apparatus, and I therefore will not repeat.

I observe that this apparatus was contracted for under specifications No. 16-R-1, instead of No. 16-T-5.

Navy wireless specifications No. 16-R-1.—These specifications require apparatus as specified under the several paragraph headings into which it is divided. These include, first, the power-supplying appliances, such as generators, power transformers, operating key, and all of the numerous details which go to a complete power outfit; second, they require that each transmitter shall be provided with two different sorts of spark gap for alternative use, with a primary condenser, an oscillation transformer, oscillation circuits therefor, and an antenna transfer switch, so that the antenna may be used either for transmitting or receiving; third, they require receivers, together with inductances, condensers, detectors, potentiometers, and telephone receivers therefor; fourth, they require measuring instruments, including a current-measuring instrument for measuring the energy transferred to the antenna and a wave meter for the measurement and adjustment of the several circuits; finally, they specify the drawings and instructions that shall accompany the apparatus, the sort of aerial to be used in testing it, and various provisions, such as workmanship, etc.

The specifications give the characteristics of the antenna with which the apparatus is to be used on page 26, paragraph 26, as follows:

"26. Dummy antenna for tests: (*a*) The dummy antenna used for tests of transmitters shall have a capacity of 0.001 mfd. for tests up to 2 kw. and a capacity of 0.002 mfd. for 5-kw. sets, and the resistances used at the different wave lengths shall be as follows:

	Ohms.
600 meters	8
750 meters	5
1,000 meters	3
2,000 meters	5
4,000 meters	8
7,000 meters	12

"For tests of receivers the capacity shall be 0.001 mfd. and the resistances as above.

"(*b*) Transmitters will be tested at full load on wave lengths of 600, 750, 1,000, and 2,000 meters, in accordance with the requirements of paragraphs 14 (A) (*f*) and 25. Receivers will be tested at wave lengths of 600, 750, 1,000, 2,000, and 4,000 meters, and in the case of long-wave receivers at 7,000 meters. A test of the transmitter at maximum power attainable will also be made at 300 meters."

The expression "dummy antenna" refers to a circuit employed in testing, which is arranged to have the same inductance and capacity as an actual antenna with which the apparatus is required to work, but has these arranged in the form of a closed circuit in order that no actual radiation may take place. The reason for this is that if, during the testing, electric waves were actually radiated, any commercial operation conducted by other stations in the neighborhood might be interfered with. In order, however, that the antenna may have the energy-dissipating qualities of an [fol. 337] actual antenna (without which an adequate test could be made) a resistance is included, which resistance corresponds both to the actual resistance of the intended working aerial and also to an amount of resistance sufficient to represent the energy dissipation due to radiation. The specifications require (page 26, paragraph 25b) that the energy radiated shall be 45 per cent of that supplied to the motors driving the power generator. The resistance is proportioned to the characteristics of an actual antenna, as determined by experience.

The abbreviation "kw." appearing in the designations "2 kw." and "5 kw." stands for the word "kilowatt," which is the electrical unit used in measuring considerable quantities of electric power. The fundamental practical unit of electric power is the watt, and 746 watts are equal to 1 horsepower. Electrical power in considerable quantity is measured in terms of a unit which is 1,000 times as great as the watt, and this is called 1 kilowatt. One kilowatt is therefore substantially equal to $1\frac{1}{3}$ horsepower. To convert the power expression "kilowatt" into the power expression "horsepower" it is therefore only necessary to multiply by one and one-third. Thus, 2 kw. equals $2\frac{2}{3}$ horsepower and 5 kw. equals $6\frac{2}{3}$ horsepower.

Another provision regarding the minimum capacity of the actual antenna with which the apparatus should be required to work is given on page 25, section 25 (*a*), as follows:

"(*a*) The transmitters of 5-kw. sets shall be designed so as to work satisfactorily on all wave lengths from 600 to 2,000 meters, with a minimum antenna capacity of 0.0012 mfd. The transmitters of 2 kw. sets shall comply with the above except that the minimum antenna capacity shall be 0.0007 mfd. The transmitters of both 5 kw. and 2 kw. sets shall work satisfactorily at wave lengths of from 300 to 600 meters with a suitable antenna."

Other portions to which I call attention are as follows: Page 17, paragraph 14 (*a*), as follows:

"14. Oscillation transformer: (*a*) The oscillation transformer to consist of two inductively coupled coils, with means for variation of coupling over a wide range. This range to include an indicated and easily made adjustment for close coupling over the entire range of wave lengths when used with an antenna, as specified in paragraph 25 (*a*). The change of coupling to be made preferably by mechanical movement of one coil with relation to the other."

Page 18, paragraph 14 (A) (*e*), as follows:

(*e*) The contractor shall furnish means by which the transmitting wave lengths can be quickly and easily changed and the apparatus marked so that the transmitting wave length is known without recourse to diagrams or tables. Facility for rapid changes is required for military purposes."

On page 19, paragraphs 16 (*a, j, k, l, n*), as follows:

"16. Receivers: (*a*) Two receiving sets will be furnished for each outfit, as follows:

"(1) One highly selective receiver of special design for receiving wave lengths from 300 meters up to 7,000 meters, to be provided with a variable condenser in primary circuit, with leads which can be operated by switches to put this condenser in series or in parallel with inductance, or to cut it out.

[fol. 338] "(2) One highly selective receiver with variable condenser for primary circuit as required for receiving waves from 200 to 4,000 meters."

"(*j*) Means shall be provided for broadening the tuning of the receiver for the purpose of picking up signals over a wide range with minimum variation of the circuits and for receiving strongly damped signals to best advantage. A method involving direct coupling will be considered in this connection.

"(*k*) Means shall be provided whereby the wave lengths of received signals may be directly indicated in the closed circuit, and a scale provided in the antenna circuit for entry of calculated values depending on the antenna used.

"(*l*) Receiving systems wherein the individual circuits may be placed in resonance as a unit with each other and with the incoming signals, by the manual operation of a single mechanical element, will be given preference."

"(*n*) The closed circuits of receivers shall be carefully adjusted and calibrated for all combinations provided for obtaining the various tunes, and the setting of the different parts of each for any tune shall be shown on a table provided in duplicate and installed for conveniently consulting it. This is in addition to the requirements of paragraph (*k*)."

On page 20, paragraph 16 (B) (*a*), as follows:

"(*a*) In all resonant circuits of the receiver the condensers must be of the variable air dielectric type."

One page 21, paragraph 16 (C) (*c*), as follows:

"(*c*) Rectifiers shall be furnished in two types in each receiver, one being relatively unaffected by static or powerful signals for ordinary use, and the other being highly sensitive for use on weak signals."

On page 22, paragraphs *a*, *b*, and *c*, as follows:

"(*a*) An approved type of wave meter with accessories to be supplied by the contractor.

"(*b*) The wave meter shall be adapted to measure—

"(1) Transmitter wave length by rectifier and telephone.

"(2) Transmitter wave damping by hot wire milliammeter or wattmeter.

"(3) Transmitter resonance curves by milliammeter or wattmeter.

"(4) Wave length of distant station by rectifier and telephone.

"(c) The wave meter shall be adapted for generation of waves for calibrating receiving apparatus and exciting antennae by approved buzzer excitation."

Page 24, paragraph 22 (*a*), as follows:

"(*a*) The contractor shall supply with the first delivery of the outfit, in addition to the blue prints, etc., furnished with his bid, a complete set of right-reading Vandykes and carbon-backed typed directions, showing over-all dimensions, location of terminals, details, diagrams of elementary and actual connections of the appliances, with values of resistance, inductance, and capacities entered, and *directions on all points necessary* and desirable in the installation, adjustment, and operation of motor generator, transmitter, spark gap, receiver, antenna, panels, and other [fol. 339] accessories, and for *maintaining resonance* under the various conditions of operating for wave lengths of from 300 to 2,000 meters." (Italics mine.)

Thus it appears from these specifications that the elements indicated as assembled in plaintiff's Exhibit No. 95 are, according to the specifications, to be provided with all of the necessary means for establishing resonance between the circuits in use, together with a wave meter for the purpose of assisting the tuning to resonance, and full directions for maintaining resonance of all the circuits under the various conditions of operating for wave lengths from 300 to 2,000 meters.

Examination of Exhibit No. 69, contract of January 31, 1914, shows that none of these requirements of specification No. 16-R-1 are modified by the special terms of the contract, and it is evident therefore that this Kilbourne & Clark apparatus contains the elements and adjusting devices arranged and in use adjusted so that there is at the transmitter a power circuit, shown in yellow in Exhibit No. 95, to charge the condenser *e* of a reservoir circuit, shown in red, which by virtue of resonance with the antenna circuit efficiently transfers energy there to cause effective radiation of elec-

tric waves, and that these are to be received at the receiving station by an antenna circuit, shown in black, tuned thereto and the energy then transferred to the conserving and utilization circuit, shown in red, by virtue of the resonant adjustment of this red circuit to the black circuit, there to be detected by the detector T and indicated by the indicator R in the green circuit.

The apparatus of Kilbourne & Clark therefore contains the elements arranged and operating, as set forth in the Marconi patent No. 763772 and recited in the claims to which my attention has been called.

It appears from the testimony of Mr. Weagant that the detector employed with this Kilbourne & Clark apparatus was similar to Exhibit No. 94, and hence a crystal detector, and what I have said as to the detector when considering the Wireless Specialty Apparatus Co. receiver, applies to this Kilbourne & Clark receiver.

Comparison of Marconi patent with apparatus manufactured by the Navy.—This apparatus is diagrammatically illustrated in plaintiff's Exhibit No. 93 and described in the testimony of Mr. Weagant. I have personally seen one of the transmitters manufactured by the Navy, but so far as I remember I have not seen a receiver. I saw the transmitter on a visit to the navy yard at Bremerton in the spring of 1916.

It is evident from an examination of Exhibit No. 93 that the transmitter there shown is identical with that of the Wireless Specialty Apparatus Co. and that it is provided with all of the adjusting means for placing the circuits in resonance to obtain the efficient transfer of energy from the red to the black circuit. What I have said as to the transmitter of the Wireless Specialty Apparatus Co. therefore applies to this transmitter of the Navy, as to the Marconi patent in suit and the claims thereof in issue, and I will not repeat.

[fol. 340] The receiving apparatus of Exhibit No. 93 made by the Navy is identical with that of the Telefunken type, already considered, save that the primary condenser *h* is indicated as in only one of the two positions shown in Exhibit No. 79. As I pointed out, this condenser is merely an additional adjusting means. In this receiver, as in that of the Telefunken type, the primary coil *j'* of the oscillation transformer performs the function of the coils *g'* and *j'* of the Wireless Specialty Apparatus Co. arrangement, it be-

ing immaterial in a receiver having variable coupling, whether these two windings are mechanically separate or mechanically joined together as one structure.

All that I have said with respect to the Telefunken receiver and, with the exceptions there noted, all that I have said with respect to the Wireless Specialty Apparatus Co. receiver apply to the receiver manufactured by the Navy, which, like those just referred to in my opinion, illustrates the combinations of elements and modes of operation set forth in the Marconi patent and particularly referred to in the claims thereof in issue.

Comparison of Marconi patent with Wireless Improvement Co. transmitter and Simon transmitter.—These two transmitters are shown, respectively, in plaintiff's Exhibits 88 and 89 and described in the testimony of Mr. Langley. The Wireless Improvement Co. transmitter is the subject of plaintiff's Exhibit No. 55, contract No. 415, from which it appears that the contract requires the apparatus to conform to specifications No. 16-R-1, already fully considered, except as modified in the contract itself, and it appears therefrom that there is no modification of the contract except as to the particular ranges of wave lengths desired.

The Simon apparatus is the subject of Exhibit No. 70, contract of September 2, 1915, and the specifications, being attached to the contract under Schedule 8121. These specifications relate only to the transmitter and do not differ materially from those which I have already considered, namely, No. 16-T-5 and No. 16-R-1.

These two transmitters are identical with that of the Wireless Specialty Apparatus Co. with one single exception in the Wireless Improvement Co. transmitter, namely, that the oscillation transformer secondary *d'* is not adjustable, so that there is in the circuit only one instead of two means of adjusting the time period.

Since these two transmitters are in all substantial respects identical with that of the Wireless Specialty Apparatus Co., which I have fully considered and compared, it seems unnecessary to repeat the explanations and comparisons, as they may be taken as though made directly with respect to each of these transmitters, namely, that of the Wireless Improvement Co. and that of Simon. Each, in my opinion, has the elements and mode of association and

operation disclosed in the Marconi patent No. 763772 and referred to in the transmitter claims thereof in issue.

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[fol. 341] I may say that in the commercial use and in the use made by the Navy Department of its wireless apparatus it is inevitable that a receiver of one type should be used with transmitters of all the different types employed by the corresponding station and that, conversely, any transmitter will naturally transmit to all of the different receivers employed at the different stations with which it may have occasion to work. All of these receivers that I have considered are provided with means for making the adjustments to the range of wave lengths used by the Navy Department and in commercial practice (except for transoceanic communication), and hence it is quite immaterial whether a particular transmitter is used with a receiver of the same make or some other.

I note that in describing these two transmitters Mr. Langley calls attention to the fact that in the Simon transmitter the condenser *e* is connected across the power transformer directly, while the spark gap G is in series with the oscillation transformer primary *d*, whereas in the Simon transmitter it is the spark gap that is in shunt with the power transformer directly, while the condenser is in series with the oscillation transformer primary. I note that similar differences will be found in the other transmitters. Thus, the Kilbourne & Clark and the Telefunken transmitters have the spark gap directly across the power transformer, while the Wireless Specialty Apparatus and Navy type transmitters have the condenser across the power transformer. I have ignored this difference because, as Mr. Langley points out, it is universally recognized to be entirely immaterial, the actual connection being determined merely by considerations of convenience in assembling in each case. The reason why it is immaterial is that the charging current flowing to the condenser occurs at a low frequency, and for such low frequency the oscillation transformer amounts merely to a direct connection; hence, although there is an apparent difference in the diagram, there is no difference in fact.

I note that this Wireless Improvement Co. 5-kw. transmitter, referred to in the contract, Exhibit No. 55, and which according to the contract was to be delivered at "U. S.

Naval Radio Station, Radio, Va.," is apparently described in the article by Captain Bullard, contained in plaintiff's Exhibit No. 81, Bullard article in the Proceedings of the Institute of Radio Engineers, pages 431, 434; diagrams and photographs are shown on pages 432, 433, and 435.

10. Question. Please answer Q. 9 and make the comparison requested in that question but substituting for the defendant's wireless apparatus referred to in that question the defendant's apparatus contracted for in plaintiff's Exhibit No. 57, contract No. 14746, dated April 22, 1911, between Fritz Lowenstein and the United States Navy Department, which apparatus is described in the depositions, respectively, of Messrs. Graham and Weagant, and [fol. 342] the receiver of which Lowenstein apparatus is illustrated in plaintiff's Exhibit No. 96, drawing, Lowenstein type of receiver. In making this comparison you may refer to any other exhibits introduced herein and make any drawings or sketches you consider necessary.

Answer. *Comparison of Marconi patent with Lowenstein apparatus.*—Transmitter: It appears from the contract, Exhibit No. 57, that the Lowenstein apparatus contracted for under Navy specification No. 16-T-5. Additional specifications are attached to the contract, which is also accompanied by a drawing illustrating the apparatus diagrammatically. I produce herewith a simplified diagram, following the conventions and letters of reference which have heretofore been used, showing the Lowenstein transmitter, a photographic copy of which is inserted opposite this page. (Plaintiff's Exhibit No. 101.)

In this diagram, as in the others I have considered, the power supply arrangements are diagrammatically indicated in yellow and comprise a generator *a*, key *b*, and transformer *c*. The primary circuit of the transmitter is shown in red and comprises the condenser *e*, spark gap G, and a common portion *d* of an inductance, included between the arrows 4 and 5. The antenna circuit is shown in black and comprises the elevated capacity area *f*, vertical wire A, loading inductance coils *g*, adjustable by the arrows 1, 2, 3, and the common portion *d'* to other inductances at the lower end of which the connection passes to earth at E.

The Lowenstein transmitter is provided with a switch by means of which the operator has only to place the switch in one of several operative positions to select the desired one

of several wave lengths, and at the same time preserve the resonance between the circuits and the most advantageous coupling. The purpose of dividing up the inductance into three coils and similarly dividing up the oscillation transformer secondary *d'* into two coils is to enable this changing of wave lengths with preservation of resonance and coupling to be done. In other words, it is an incident of the particular mechanical construction employed by Lowenstein. In electrical effect the action is precisely the same as though the three coils *g* were formed as one and the two coils *d'* as one.

The adjustment of time period of the reservoir circuit is accomplished by the two contacts 4, 5, and the adjustment of both the time period and the coupling is effected by adjusting the contact 1, 2, 3, with particular reference to the adjustments already made of 4 and 5.

I note that the Navy manual for 1911, on page 95, gives a diagram, Figure 47, of this Lowenstein apparatus, which is substantially the same as that which I have just made from the drawing T 8 of contract. Regarding this Figure 47, the manual says, on page 96, as follows:

"Figure 47 indicates a method of connecting up sending sets so that the operator by moving a hand wheel or lever can change the wave length of the open and closed circuits the same amount without changing the coupling. This apparatus is just being introduced and should greatly facilitate the operator's control over his sending wave length."

[fol. 343] It will be seen that this Lowenstein transmitter has all the elements of the transmitter Figure 1 of the Marconi patent No. 763772, differing therefrom in electrical arrangement only in that the oscillation tranformer is of the autotransformer type instead of the inductive type. It is therefore substantially identical with the Telefunken transmitter of Exhibit No. 79, which I have already fully considered. As I have there fully explained the substantial identity and complete likeness of function between these two sorts of transformers, I will not here repeat.

This transmitter is identical with the Wireless Specialty Apparatus transmitter except as to this transformer, and what I have said, therefore, in comparing the Wireless Specialty Apparatus Co. transmitter with the Marconi patent may be taken without repetition here as applying to the Lowenstein transmitter.

That the circuits are in resonance is shown not only by the specification No. 16-T-5, but also by the additional specifications accompanying the contract; for example, items *j* and *k*, which read as follows:

"*j*. The closed and open circuits of the transmitter are automatically adjusted to syntony at the five wave lengths between 425 and 1,000 meters and easily syntonized for any wave length between these limits.

"*k*. The transmitter supplied is especially designed for resonance. No auxiliary apparatus is required to obtain resonance."

Paragraph 12 (*a*) states:

"The recommended normal percentage of coupling is 22 per cent to 25 per cent, which is automatically maintained constant at all the five available wave lengths. Provision of varying this coupling, if desired, is provided."

I also note that the resonance of the two circuits is indicated in the above quotation from the Navy manual of 1911.

It is therefore evident that transfer of energy from the reservoir circuit to the antenna circuit is affected by the tuning of the two circuits to resonance with one another, and I therefore find that this Lowenstein transmitter is such a transmitter as is set forth in the Marconi patent No. 763772 and referred to in the tranmitter claims in suit, both as to the elements and their mode of combination and operation.

* * * * * * *

Lowenstein receiver.—The Lowenstein receiver is shown in Exhibit No. 96, and is described by Mr. Weagant in his testimony. I find in the Lowenstein contract, Exhibit No. 57, two receivers marked, respectively, "Alternative receiver proposal No. 1" and "Alternative receiver proposal No. 2." It appears from the contract that alternative receiver proposal No. 1 was accepted by the Navy Department. Exhibit No. 96, produced by Mr. Weagant, is a diagrammatic illustration of the drawing R-8, at- [fol. 344] tached to Exhibit No. 57. It will be seen that this receiver is substantially identical with that of the Wireless Specialty Apparatus Co., shown in Exhibit No. 87. The

specific differences are that the antenna circuit has a condenser h connected therein, this being merely an additional adjusting means in the antenna circuit, and the secondary or red circuit has an additional inductance j^3 therein variable as indicated at 3, this being merely an additional means of adjustment for the secondary circuit. This coil j^3 corresponds to the coil g^2 of Figure 2 of the Marconi patent No. 763772. Everything that I have said in comparing the receiver of the Wireless Specialty Apparatus Co. with the Marconi patent No. 763772 applies to this Lowenstein receiver and I will not repeat.

* * * * * * *

11. Question. Please answer Q. 9 and make the comparison requested in that question but substituting for defendant's radio apparatus referred to therein the apparatus of the radio pack sets made by the United States Signal Corps and referred to by Mr. Weagant in his deposition, the defendant's radio pack sets made by the National Electric Supply Co. for the United States Signal Corps, also described by Mr. Weagant in his said deposition and referred to in plaintiff's Exhibit No. 51, contract of June 23, 1914, between said company and the United States Signal Corps, and also the defendant's portable field radio sets of the two-trunk type of the National Electric Supply Co., described by Mr. Graham in his deposition and illustrated in plaintiff's Exhibit No. 80. In making the comparison called for you may refer to any other exhibit introduced herein and make use of any drawings or sketches you deem necessary.

Answer. *Comparison of Marconi patent in suit with Army pack sets.*—Radio pack sets manufactured by United States Signal Corps: It appears from the testimony of Mr. Weagant that these pack sets manufactured by the United States Signal Corps are electrically substantially identical with those manufactured by the Navy and diagrammatically illustrated in plaintiff's Exhibit No. 93. He says also that their mode of operation is the same.

As I have already considered the transmitters and receivers manufactured by the Navy and diagrammatically indicated in Exhibit No. 93, I will ask that what I have there said be taken as applying also to this Signal Corps pack set.

National Electric Supply Co. portable field radio sets, two-trunk type, installed on U. S. S. *Georgia:* The trans-

mitter of this set, as shown in Exhibit No. 80, corresponds in the arrangement of its parts to Figure F of plaintiff's [fol. 345] Exhibit No. 99, Waterman drawing of Marconi and Lodge patents, to tune 6 of the table given on page 4 of the Marconi patent in suit No. 763772. It has the power supply circuit shown in yellow, comprising a generator *a*, key *b*, and transformer *c*; the reservoir circuit shown in red comprising the condenser *e*, spark gap G, and oscillation tranformer primary coil *d* and the antenna circuit shown in black comprising the capacity area *f*, wire A, oscillation transformer secondary *d'*, earth connection E. The antenna circuit has adjustable contacts 1 and 3 and the red circuit contacts 2 and 2ª. This transmitter is evidently arranged therefor to have the circuits tuned to resonance and to operate in an efficient and practicable manner, it would be necessary that the circuits should be so tuned. So connected and adjusted, the efficient transfer of energy referred to in the Marconi patent No. 763772 would be realized and this transmitter in my opinion contains the elements and combinations and would operate in a manner described in the patent and referred to in the transmitter claims thereof.

It does not have a separate inductance coil in the antenna circuit, but, as I have explained, it is not material that as a matter of mechanism or mechanical arrangement the loading coil *g* of Marconi, Figure 1, which is in fact the Lodge loading coil of Lodge patent No. 609154, should be separate from the secondary of the oscillation transformer, as the two may be combined. Where the coupling of the two circuits is variable the single coil *g'* is made to serve the purposes of both coils by the suitable adjustment of the coupling. According to Mr. Graham's testimony, the coupling of this transmitter is variable and hence I am of the opinion that there is embodied in this transmitter the variably acting inductance coil of the Lodge patent, giving the desired definiteness to the waves radiated and enabling the wave length to be adjusted.

The receiver of this set is practically identical with the type E-4 receiver of the Telefunken apparatus, shown in Exhibit No. 79, and what I have said with respect to that receiver applies fully to this National Electric Supply Co. receiver, and I will not repeat. It is my opinion that the apparatus of Exhibit No. 80, as described by Mr. Graham, embodies the construction and mode of operation of the

Marconi patent in suit, and particularly as recited in the claims thereof to which my attention has been called.

I may say that this apparatus differs from that of the Wireless Specialty Apparatus Co. only in details, such as the combination of the inductance coils *g*, *g'*, with the oscillation transformer coils *d'*, *j'*, and in the omission of the variable secondary condenser in the receiving station. These differences do not essentially alter or modify the mode of operation, and therefore what I have said as to the mode of operation of the Wireless Specialty Apparatus Co. system in comparing it with the Marconi patent in suit, applies to that of the National Electric Supply Co. field-pack set.

National Electric Supply Co. pack sets manufactured for the United States Signal Corps, model 1914: This apparatus is shown in drawing No. 988, forming part of Exhibit No. 51, National Electric Supply Co. contract. It is also described in the testimony of Mr. Weagant (MS. 249-250). I find the same drawing, reproduced on page 109 of the [fol. 346] Signal Corps book Radiotelegraphy, 1914, and the set is described on pages 101 to 114 thereof.

The drawing No. 988 when put in simpler diagrammatic form is identical with exhibit No. 80, National Electric Supply apparatus, with the single exception that the oscillation transformer is of the autotransformer or direct coupled type, instead of the inductive coupled type, shown in the drawing of this company's apparatus, Exhibit No. 80. As I have already explained, this does not alter the principle or mode of operation in any way and the drawing No. 988 shows that the coupling is capable of variation, so that the secondary of the oscillation transformer also performs the function of the Lodge loading coil.

Regarding the tuning of the transmitter, I quote as follows from pages 105 and 106:

"Tuning of sending set: The tuning of the closed and open circuits to resonance, and the determination of the correct coupling between them are the two most important adjustments in a quenched-spark transmitter. In the present type of directly coupled set with a flat spiral as the oscillation transformer, these adjustments can be made either with or without the help of a wave meter. If made without the meter, the adjustments should satisfy the following tests: (1) the number of turns in the closed circuit

should be chosen to give the desired wave length; (2) the antenna hot-wire ammeter should show the maximum reading; (3) the note should be clear and characteristic of 500 cycles. These adjustments are in general dependent on each other, an incorrect change in one seriously affecting all the others. As shown in the table, the position of the clips in the closed circuit determines the proper turns in the spiral to give the desired wave lengths.

"The number of turns in the open or radiating circuit necessary to bring it into resonance with the closed circuit must be found by trial, although the numbers shown in the table below are approximately correct and should be used in beginning to make the adjustments. * * *

"If the circuits are in resonance and the coupling is correct, the antenna hot-wire ammeter should read not less than 2.2 amperes, and may read as high as 3.0 amperes. If the ammeter reading is low, then either the coupling is too loose or the circuits are not in resonance, and one or both of the clips must be moved so as to get the highest possible reading consistent with a clear note. It is impossible to indicate which clip is to be moved or in which direction; but, if possible, the counterpoise clip should be kept on the outside turn."

The tuning of the receiving set is described on pages 110 and 111, from which I quote as follows:

"Tuning of the receiving set: First the detector must be adjusted to a sensitive point by means of the test buzzer, the note of which should be clearly heard in the receiving telephones when it is held near the antenna or counterpoise wires or the coil windings. When the wave length of the sending station is known the number of turns in the primary and secondary coils and the coupling should be set according to the values in the above table, which will be approximately correct for all sets using the standard antenna. When the wave length is unknown, then signals can be found only by repeated trials of different combina-
[fol. 347] tions of turns and couplings, in which, however, consistent sets of values may be taken from the table. Whence once the signals have been heard such further adjustments of primary and secondary turns and coupling should be made as will give the maximum sound in the telephones. In general it will be found that when there

is interference or static troubles the sharpest tuning and the best protection from interference will be obtained when the loosest coupling is used; that is, when the secondary is pulled out as far as possible and still hear the desired station. * * *

"If the receiver is used with the standard antenna and signals are being received from an unknown station, the table of wave length can be used to determine approximately the wave length of the unknown station."

The description of the operation which I have given as to the Wireless Specialty Apparatus Co. system applies as to this system also and I will not repeat. In my opinion this pack set embodies the constructions and modes of operation of the Marconi patent in suit, particularly as recited in the claims thereof, to which my attention has been called.

12. Question. Begininng at page 81 of plaintiff's Exhibit No. 90, Radiotelegraphy, 1914, there is described certain "radio apparatus in use in the Signal Corps." On pages 91 to 101 there is described and illustrated certain field-wagon sets used by the United States Signal Corps and known as the "Telefunken two-wagon 2-kilowatt set." Have you read the description of these field-wagon sets and examined the illustrations referred to; and if so, do you understand same?

Answer. I have read the matter referred to and understand it.

13. Question. Please make the comparison called for in Q. 9, substituting, however, for the defendant's apparatus referred to in that question the defendant's Telefunken "two-wagon 2-kilowatt set," referred to in the last question and answer, and described and illustrated in plaintiff's Exhibit No. 90, pages 91-101.

Answer. The apparatus described in the portions of Exhibit No. 90, referred to, is in elements and arrangement and in mode of operation identical with that shown in plaintiff's Exhibit No. 79, drawing, Telefunken apparatus, the receiver of Exhibit No. 90, as shown on pages 94 and 98 thereof and described in the text, being identical with the E-4 receiver of Exhibit No. 79. The text describes the adjustments of the transmitter on pages 92 and 93 to 97, inclusive, and the adjustments of the receiver on page 92 and on pages 97 to 101, inclusive. It is evident from this descriptive matter that the circuits are adjusted to resonance,

both in the transmitter and in the receiver, in the same manner as I have described with reference to Exhibit No. 79, Telefunken apparatus, and also in similar manner to the description which I have given with reference to the Wireless Specialty Apparatus Co. transmitter and receiver of Exhibit No. 87. The text on page 99 calls attention to one means used in tuning to which I have not hitherto especially referred. It is stated on page 99 as follows:

"Operator then varies his condenser and also the coupling between the primary and secondary of the receiving transformer until he gets the best adjustment. Changing the coupling; that is, pulling the secondary away from or pushing it closer to the primary, changes the wave length, though not to as great an extent as does varying the con- [fol. 348] denser. Some stations can not be heard at all well unle the secondary coil is pulled some distance away from the primary."

The reason why the coupling affects the tuning is that it affects the capacity of the coils. Coils have, as I have stated, not only inductance but also capacity. This capacity is affected by the surroundings just as the inductance is also affected by the surroundings if there be iron in the neighborhood. Changing the capacity of course changes the time period or wave length. This is true not only of the Telefunken apparatus but is true in general of wireless telegraph receivers, being true also of the apparatus of the Marconi patent No. 763772 in suit.

I call attention to the fact that the descriptive matter on pages 96 to 101 describes and illustrates the calibration; that is to say, the ascertainment and tabulation of the tuning or resonance adjustments for various wave lengths.

In view of the substantial identity of this apparatus with that of Exhibits 79, Telefunken apparatus, and No. 87, Wireless Specialty Apparatus Co. apparatus, I will ask that the comparison of these which I have made with the subject matter of the Marconi patent in suit and the claims thereof in issue be understood as referring also to this Telefunken field-wagon apparatus.

14. Question. Have you examined plaintiff's Exhibit No. 53, contract No. 8503, dated June 27, 1910, between the Foote-Pierson & Co. and the United States Signal Corps, for the manufacture and delivery to it of eight wireless

pack sets under Signal Corps wireless specification 410, and have you examined said specification and plaintiff's Exhibit No. 98, Signal Corps drawing No. 741, field wireless pack set (two-trunk type), and do you understand the construction and mode of operation of such wireless sets, referred to in said exhibits?

Answer. I have examined Exhibits Nos. 53 and 98, referred to, and understand same.

15. Question. Please make the comparison called for in Q. 9, substituting, however, for defendant's apparatus, referred to in that question, the Foote-Pierson pack sets of plaintiff's Exhibits Nos. 53 and 98, mentioned in the last question. You may in answering the question refer to any other exhibit and make any drawings or sketches you deem necessary.

Answer. I have made a sketch, employing the same conventions as the other diagrammatic illustrations which I have been using, and illustrating this Foote-Pierson apparatus, as shown in Exhibit No. 98. (Sketch, plaintiff's Exhibit No. 102.) I understand that Exhibit No. 98, being drawing No. 741-1, is one of the drawings referred to in the specification No. 410 attached to the Foote-Pierson contract, Exhibit No. 53, and referred to therein. This Foote-Pierson apparatus does not differ in any important respect from the National Electric Supply Co., field radio pack set, as shown in plaintiff's Exhibit No. 80. By comparison of my sketch with Exhibit No. 80 it will be seen that the only difference is that the Foote-Pierson apparatus of specification No. 410 has both the transmitting and receiving [fol. 349] oscillation transformer of the direct coupled or autotransformer type.

As I have already explained, this change in the form of the oscillation transformer does not in any way alter the operative relation of the two circuits nor change the mode of operation of the apparatus. The mode of operation which I have set forth in considering the Wireless Specialty Apparatus Co.'s apparatus applies fully to this Foote-Pierson pack set. I note that the specification No. 410 appears to be devoted exclusively to the constructional features and does not deal with the operation. The elements and the adjustments provided, however, indicate clearly the adaptability of the apparatus for the tuning of the circuits to resonance, and this is their evident function. Regarding

the detector employed with this set the specification states, paragraph 11:

"Silicon detector: This shall be the standard silicon detector as made by the Wireless Specialty Co., 81 New Street, New York, and shall be furnished with nickel plated mounting, retaining chain for button and fittings complete for connection to the wireless receiving set."

This detector, here designated, is substantially like Exhibit No. 94, Wireless Specialty silicon detector, except that one of the contact points (the movable one) is a metal instead of a crystal contact. Its operation is the same and has already been described.

I also note that the spark gap in the transmitter appears to be a so-called open gap instead of the quenched spark gap of the National Electric Supply Co. set. It is common with the very small sets using small power to use this simpler form of gap. The operation of these gaps differs in regularity and perfection of result but the mode of operation of the apparatus is not altered.

Since the elements, mode of assemblage and operation is substantially the same as in the case of the National Electric Supply Co. type, shown in Exhibit No. 80, and differs only in minor details from the more elaborate apparatus of the Wireless Specialty Apparatus Co., illustrated in Exhibit No. 87, while the operation is the same in substance, I will not repeat the detailed comparison which I have made in considering these other types but will ask that they be understood as applying to this Foote-Pierson apparatus also.

Mr. Cosgrove: Plaintiff's counsel offers in evidence the following:

Navy manual for the year 1911, referred to by the witness in answer to Q. 10 and requests that the same be marked "Plaintiff's Exhibit 100, Navy manual of 1911."

Also the simplified diagram of Lowenstein transmitter produced by the witness in answer to Q. 10 and requests that the same be marked "Plaintiff's Exhibit 101, Waterman sketch, Lowenstein transmitter."

Also the simplified diagram produced of the Foote-Pierson pack set referred to by the witness in his answer to Q. 15, and requests that the same be marked "Plaintiff's Exhibit 102, Waterman sketch, Foote-Pierson pack set."

Also certified copy of Signal Corps Bulletin No. 17, "Instructions for operating field radio pack set, model of 1912," and requests that the same be marked "Plaintiff's Exhibit No. 103, Signal Corps Bulletin No. 17."

[fol. 350] 16. Question. Have you examined plaintiff's Exhibit No. 54, contract No. 445, dated October 24, 1910, between the North American Wireless Co. and the United States Signal Corps, and also plaintiff's Exhibit No. 42, Army wireless specification No. 547, referred to in the said contract? If so, please state whether you understand the same.

Answer. I have and do.

17. Question. Please compare the construction, arrangement, and mode of operation of the defendant's North American Wireless Co. wireless apparatus of plaintiff's Exhibits Nos. 42 and 54, referred to in the last question, with that of the inventions of the Marconi patent in suit, as recited in the claims in issue herein of those patents.

Answer. Exhibit No. 54 provides for a 2-kilowatt transmitter having a wave-length range from 300 to 2,000 meters, provided that the natural period of the antenna corresponds to a wave length of 250 meters or less and the electrostatic capacity of the antenna is approximately 0.0015 mf., and a receiver of the same wave length. This provision thus substantially fixes the characteristics of the antenna. It further appears from the specification No. 547, Exhibit No. 42, that the transmitter is to consist of two circuits adjusted to resonance, and the character of the primary condenser is specified. It is also required that the apparatus shall have means for rapidly changing to any desired wave length and that the wave length shall be permanently marked so that the adjustments may be made by reference to calibration curves or tables.

The particular construction of the oscillation transformer as to whether it is of the autotransformer or the inductive type does not appear from the contract or specification, but as I have pointed out, it makes no difference in the mode of operation or in the substantial organization of elements whether it is of one sort or the other. There is in either case substantially the same combination of elements as is found in the apparatus of the Wireless Specialty Apparatus Co., and it is immaterial whether the transformer for the high frequency energy has two mechanical distinct coils

d, *d'*, as does the Wireless Specialty Apparatus Co. transmitter, or whether these coils constitute a single structure as in the case of the Telefunken transmitter of Exhibit No. 79. The description which I have given of the arrangement and mode of operation of the transmitter of the Wireless Specialty Co. applies in either case.

With regard to the receiver, it appears that the same is to be provided with tuning condensers having air dielectric corresponding to the condensers *h*, *h'* of Figure 2 of the Marconi patent No. 763772, as I understand, and receiving inductances, and that the two circuits shall be in resonance with one another. It is also provided that the receiver shall have a capacity for adjusting to various wave lengths from 300 to 2,000 meters and also for broad tuning so as to receive signals over a wide range of wave length with a minimum of adjustment when required. The contract guarantees a high degree of selectivity, so that a variation of 3½ per cent from the wave length to which the circuits of the receiver are tuned will cut down the strength of an interfering signal to one-third of its strength before the variation of 3½ per cent was made.

[fol. 351] It is evident to me from this description that the receiver is substantially the same as that of the Wireless Specialty Apparatus Co., and the description which I have given and the comparison which I have made with respect to the appliances of that company apply as to the apparatus of the North American Wireless Co. and I will not repeat. It does not appear whether the oscillation transformer for the receiver is of the direct or the inductively coupled type, but, as I have pointed out, it is immaterial as far as the substantial features of combinations and operation is concerned which form is used.

I may note that the term "dielectric" used above designates the insulating material separating the plates of the condenser, which in the particular instance of the receiving condenser is required to be air. The reason for this is that air has practically no losses when employed as the dielectric of the condenser; thus the small amount of energy received will not be wasted in condenser losses.

The specification No. 547 requires that the detectors supplied with the receiver shall be equal in sensitiveness to those of the electrolytic type, but I do not find that the contract, Exhibit No. 54, specifically describes the construction of the detector.

In my opinion the apparatus to be furnished under the contract contains the elements, combinations, and mode of operation of the Marconi patent in suit and the claims thereof in issue and the comparison which I have made more specifically in considering the Wireless Specialty Apparatus Co. apparatus applies as to this apparatus.

18. Question. Have you read and examined the following contracts and wireless specifications, and do you understand the same: Plaintiff's Exhibit No. 47, contract 698, dated September 29, 1913, between the Atlantic Communication Co. and the United States Signal Corps for radio sets in accordance with Army wireless specification No. 566 (plaintiff's Exhibit No. 43); plaintiff's Exhibit No. 45, contract No. 14811, dated May 1, 1911, between the Garwood Electric Co. and the United States Navy for wireless telegraph sets under Navy wireless specification No. 16-T-5 (plaintiff's Exhibit No. 37); and plaintiff's Exhibit No. 71, contract No. 20437, dated March 5, 1914, between the Radio Telegraph & Telephone Co. and the United States Navy for radio sets under Navy specification No. 16-R-1 (plaintiff's Exhibit No. 38).

Answer. I have and do.

19. Question. Please compare the construction and mode of operation of defendant's Atlantic Communication Co. wireless apparatus of plaintiff's Exhibit No. 47 and plaintiff's Exhibit No. 43, referred to in the last question, with that of the inventions of the Marconi patent in suit, as claimed in the claims in issue herein of that patent.

Answer. Exhibit No. 43, specification No. 506, provides for a transmitter comprising a generator, transformer, condenser, spark gap, linking coil (oscillation transformer), and loading inductances, and expresses a preference for means for automatic, simultaneous tuning of the oscillating and radiating circuits of the transmitting sets and requires that the oscillating and radiating circuits shall be [fol. 352] provided with the necessary tuning inductances for preserving proper coupling for all radiating conditions.

The receiving set is required to have high selectivity and also to have provision for broad tuning. It is further required as follows:

"The antenna circuit shall be capable of tuning over a large range of wave length, which must be stated in the bid, including those below the fundamental of the antenna.

The secondary circuit shall be capable of broad as well as highly selective tuning, and proper means for this variation must be provided. Coupling between the antenna and the secondary circuit shall be variable.

"Mineral detectors are required, and no other type will be acceptable."

The necessary potentiometer and telephone receivers are also required. The contract, Exhibit No. 47, is accompanied by a diagrammatic drawing illustrating the transmitter and receiver. Photographs also are attached showing such portions of the apparatus. From this drawing it is evident that the transmitter is substantially identical with that of the Wireless Specialty Apparatus Co., plaintiff's Exhibit No. 87, which I have fully described, and that the receiver is identical with that of the Telefunken type, plaintiff's Exhibit No. 79, E-4. The only difference between the apparatus illustrated in the contract and that of the Telefunken transmitter is that the oscillation transformer is inductively coupled instead of direct coupled, this being, as I have already said, not substantially different.

It appears from the letter of August 28, 1913, which is a part of Exhibit No. 47, that the transmitter is the same as the Telefunken transmitter, which I have already considered, except that the apparatus is arranged for inductive coupling, but that direct coupling can also be used by change of connection. It also appears that the receiver is "the well-known Telefunken type E–4," and that two iron pyrites and one galena detector accompany the receiver.

In view of this substantial identity with the apparatus of the Telefunken type, plaintiff's Exhibit No. 79, and the Wireless Specialty Apparatus Co., plaintiff's Exhibit No. 87, the statements which I have made in comparing these with the Marconi patent in suit apply to this apparatus also. In my opinion the apparatus referred to in the Exhibits Nos. 43 and 47, inquired about, is such apparatus as is designated in the claims of the Marconi patent in issue.

20. Question. Please compare the constructions and mode of operation of defendant's Garwood Electric Co. transmitter of Plaintiff's Exhibit No. 45 and Navy wireless specification No. 16–T–5 with that of the inventions of the Marconi patent No. 763772, as recited in the transmitter claims thereof in issue.

Answer. I have already fully considered the specification No. 16–T–5, and have shown that it calls for a complete

transmitter, substantially as set forth in the Marconi patent No. 763772, having inductively coupled oscillation transformer, and that it provides for the tuning of the circuits to resonance and means for adjusting them for different time periods. The Garwood contract, Exhibit No. 45, does not modify nor alter any of these above requirements. It [fol. 353] specifies that the exciting and radiating circuits may be rapidly and simultaneously altered in wave length without alteration of the resonance between the circuits. It also gives data as to the constants of the circuits, the voltage that is employed to charge the condenser, and other details as to the construction. From this information it is evident that the transmitter is in substance the same as that of the Wireless Specialty Apparatus Co., shown in Exhibit No. 87, and I will ask that all the comparisons which I have made and the explanations which I have given with reference to this Wireless Specialty Apparatus transmitter be understood as applying also to the Garwood transmitter, without repetition.

21. Question. Please compare the construction and mode of operation of defendant's Radio Telephone & Telegraph Co. apparatus of plaintiff's Exhibit No. 71, as set forth in that exhibit and in Navy wireless specification No. 16-R-1, referred to in said exhibit, with that of the inventions of the Marconi patent No. 763772, as claimed in the claims in issue herein in that patent, giving your reasons for any opinion you may express as the result of such comparison.

Answer. The contract, Exhibit No. 71, is for two 5-kw radio sets complete, including receivers to be made in accordance with specifications No. 16-R-1, except as modified. The modifications do not affect the specifications, except as to mechanical features and as to the particular number of wave lengths obtainable by the movement of the single switch. Nine such specified wave lengths are required by the contract.

According to the specification No. 16-R-1 the transmitter is required to include a power generator of alternating current with a transformer and transmitting key, all corresponding to the yellow circuit of the Wireless Specialty Apparatus Co. transmitter of Exhibit No. 87. It is also required to furnish transmitter condenser, corresponding to *c*, a quenched spark gap, corresponding to G, and an inductively coupled oscillation transformer whose primary corresponds to the coil *d* of the red circuit of Exhibit No.

87. The secondary of this oscillation transformer corresponds to coil *d'* of the black circuit of Exhibit No. 87. Also the specification requires the "auxiliary antenna loading coil," corresponding to *g*, and provides for the aerial and earth connection, all as indicated by the black circuit of Exhibit No. 87. All of these elements will be found to be cited on pages 1 and 2 and specified more precisely in the succeeding pages. The specifications also require all of the necessary accompanying and coordinating parts, making a complete, operative wireless telegraph transmitter.

Further, the specifications require that there shall be means of adjusting the time period of these circuits (red and black) and these means are indicated diagrammatically at 1, 2, 3 of Exhibit No. 87. Further, it requires that these adjusting devices shall be quickly and readily changeable and that the apparatus shall be marked so that the transmitting wave lengths will be known from the markings placed thereon and the circuits can be set in resonance for the various wave lengths.

It is required that the apparatus shall be accompanied by necessary drawings and prints and directions on all points [fol. 354] necessary for maintaining resonance under the various conditions of operation for wave lengths from 300 to 2,000 meters and the specifications define the characteristics of the antenna, with which the transmitters are to be connected and adjusted.

As to the receivers, it is clear from the specification No. 16-R-1, that an inductively coupled receiver is required because highly selective tuning is required, together with means for broadening the tuning when desired and only in connection with this latter does the specification say that for this particular purpose direct coupling will be considered. The wave lengths provided for vary from 200 to 7,000 meters, one receiver covering the range from 300 up to 7,000 and the other the range from 200 to 4,000. Neither the specification nor the contract states specifically whether the inductances provided for this purpose shall include the separate loading inductance *d'* or whether the inductances may all be combined in the primary *j'* of the oscillation transformer, the letters of reference referring to the Marconi patent No. 763772, Figure 2, or to Exhibit No. 87, the Wireless Specialty Apparatus Co. receiver. As I have already pointed out it is immaterial which is the case whereas in the case of this specification a variable coupling is required.

In such an event it is merely a matter of mechanical convenience in construction and arrangement, whether the coils g' and j' are separate or united. I note that the contract Exhibit No. 71 makes alternative propositions in the third clause on the second page, where it says that receivers equal in convenience of manipulation and electrical efficiency to the I-P-76 type of the Wireless Specialty Apparatus Co., or, if preferred, the I-P-76 receiver could be furnished.

It is therefore evident that the receivers proposed are either identically that shown on Exhibit No. 87 or substantially the same.

The specification provides that there shall be means for broadening the tuning and prefers an arrangement wherein by the manipulation of a single mechanical element, both circuits may be simultaneously varied and kept continuously in resonance. It requires that all the adjustable parts shall be marked with wave length scales so that the operator may instantly set the two circuits to resonance for receiving any desired wave length and specifically requiring in addition thereto that the closed circuit shall be carefully adjusted and calibrated so that all the various combinations by which the wave lengths within its range may be obtained by the adjustment of the condenser h' and of the contact 7 (Exhibit No. 87) may be at once known from the table accompanying the instrument.

It is clear from the contract and the specification referred to in the question that the apparatus called for is substantially the same as that of the Wireless Specialty Apparatus Co., both as to the transmitter and the receiver, and I will therefore ask that the descriptions, comparisons, and opinions be taken without repetition as applying to this Radio Telephone & Telegraph Co. apparatus, so far as concerns the claims in issue the Marconi patent No. 763772.

22. Question. Have you read the description of the 1915 model pack set, set forth on pages 115 to 121 of plaintiff's Exhibit No. 91, Radiotelegraphy of 1915, on pages 118 to 127 of plaintiff's Exhibit No. 92, Radiotelegraphy of 1916, the description of the 1913 model pack set on pages 104-118 of the same exhibit, and the description of the tractor sets [fol. 555] on pages 121 and 127, respectively, of said exhibits, and do you understand same?

Answer. Yes.

23. Question. Please state, in your opinion, whether or not the 1913 and 1915 model pack sets and the tractor set described in said Exhibits Nos. 91 and 92 and referred to in the last question, if constructed, installed, and operated in substantial accordance with the description of said exhibits, would be substantially similar to any of the inventions of any of the claims in issue of the Marconi patent in suit; and if so, which claims, giving your reasons for any opinion you may express.

Answer. *United States Signal Corps pack set, model 1913.* I have already considered the 1914 pack set in a preceding answer, and in considering the National Electric Supply Co.'s pack sets. It appears from the 1916 Signal Corps book, Exhibit No. 92, that the 1913 model pack set is exactly the same in all substantial particulars, and what I have said in considering the National Electric Supply Co.'s set applies equally to this. I note that in considering that set I quoted the descriptive matter appertaining thereto so far as seemed pertinent from the Signal Corps book of 1914, Exhibit No. 90. The Signal Corps of 1916 substantially repeats that description somewhat amplified but not altered in any important particular I therefore merely call attention to this description, particularly as found on pages 110 to 112, inclusive, of Exhibit No. 92, with reference to the transmitters, and pages 114 to 117, with reference to the receiver. The diagrams as given on page 109 of Exhibit No. 90 and 115 of Exhibit No. 92 are identical. The detector is said to be galena or other similar detector, hence it is a detector of the crystal variety. In my opinion, the apparatus if installed and operated as called for in the exhibits is as to its elements, combination, and mode of operation such an apparatus as referred to in the Marconi patent and the claims thereof in issue, for reasons more fully given in my consideration of the National Electric Supply Co. pack sets and the apparatus of the Wireless Specialty Apparatus Co. apparatus, to which the latter description makes reference.

United States Signal Corps pack set, model 1915.—The Signal Corps book for 1916, page 115, states that the 1915 model pack set is similar to the previous types, and that the same constructions apply, the only important differences calling for additional instructions being the construction of

the oscillation transformer and in the arrangement of the receiving set.

Transmitter: The transmitter differs from the models of 1913 and 1914, already considered, only in the use of a two-coil or inductively coupled, as distinguished from a one-coil or direct coupled, oscillation transformer. As I have explained, this is not a difference affecting the operation nor the substantial features of the construction and combination. I ask, therefore, that the comparison I have made as to these earlier transmitters be taken without repetition as applying to the 1915 transmitter.

Receiver: The following statement is made on page 118 of Exhibit No. 91 in differentiating the 1915 receiver. It will be seen that the primary difference set forth is in the method of associating or coupling the two circuits:

[fol. 356] "In the earlier sets, types A B, the two circuits were magnetically coupled; that is, the current in the primary (open or antenna) circuit induced currents in the secondary (closed or detector) circuit by means of magnetic lines which passed from the primary coil through the turns of the secondary coil. In the present set the two circuits are statically coupled; that is, the current in the primary circuit induces current in the secondary circuit by means of static lines in two coupling condensers connected in the leads between the circuits. The transfer of the energy for the operation of the detector and telephones from the primary to the secondary circuit is as efficient in this type of connection as in the other."

Substantially the same language is used in the 1916 book, Exhibit No. 92.

It will be seen from this statement that the difference which is set forth is in the coupling of the circuits, a third method of associating them being here referred to. These three methods are equivalent ways of transferring energy from the antenna circuit, in which it is received. The three methods are known, respectively, as the inductive or two-coil transformer coupling, the direct single coil or auto-transformer coupling, and the electrostatic or condenser coupling. All depend upon some one of the available ways of impressing an electromotive force upon the secondary circuit. In the inductive-coupled method, this is done through the instrumentality of the electromagnetic field,

due to the flow of a current in the primary circuit, while in the other two methods it is due to the existence of an electromotive force in the primary which is directly connected to the secondary by the use of a common coil. In the case of the direct coupling, and transferred by electrostatic field, in the case of the static coupling. As the above quotation states, the transfer of energy is as efficient in the one case as in the other and the choice is dictated merely by considerations of convenience. The electrostatic coupling is considered convenient for these pack sets because, as the description states, the construction is more rugged and the coupling involves no moving parts.

Referring to the diagrams found, respectively, at page 119 of Exhibit No. 91, and page 125 of Exhibit 92, it will be noted that there are two such arrangements possible in this receiver, and the description says that the change from one to the other is effected by a switch provided for the purpose. According to the text, the upper one of these circuits is used for shorter wave lengths and the lower one for the longer wave lengths.

Short-wave receiver: In this receiver the antenna circuit consists of the elevated conductor marked "Antenna," the two inductance coils, each of which is marked "Primary," and the earth connection marked "Ground." The secondary circuit consists of the coil marked "Secondary," the detector so marked, the telephone condenser so marked, and the adjustable connection to the secondary coil. The utilization circuit is indicated by the "telephone." The coupling of these two circuits is indicated by two condensers marked "Fixed coupling condensers," this being, as I have stated, merely another way of transferring energy to the secondary circuit. Regarding the adjustment of this re- [fol. 357] ceiver, for the reception of signals, the following instructions for tuning are given on page 126 of Exhibit No. 92:

"When comparatively short-wave lengths are to be received, as from 300 to 700 meters, the double pole, double-throw switch on top of the set should be thrown to the position marked "Short." This makes no changes in the primary circuit, but connects into circuit (1) the secondary coil with the dial switch marked "Secondary" with contacts 0 to 24 for tuning to different wave lengths; (2) detector and telephones.

"Short-wave signals should be picked up by adjustments of the large primary and the secondary dials and fine adjustments made later on the small primary dial."

It appears from this description, that in use at this short connection, the primary and secondary circuits are tuned in exactly the usual manner to resonance with the received signal and with one another. The sole difference between this receiver and those of the other pack sets which I have considered lies in the mode of coupling, which, as I have stated, does not affect in any substantial way the operation.

For this reason, the statements which I have made in comparing the receivers of the other pack sets with the claims in issue of the * * * Marconi No. 763772 patent, apply also to this receiver when installed and operated, and I will not repeat.

Long-wave receiver: When the switch provided with the receiver is thrown into its other position, the circuit shown in the lower diagram is said to be produced. I have no personal knowledge of this arrangement and the description of its operation does not give sufficient information to enable me to make intelligent comparison, and in the absence of such information I am therefore unable to comply with the request in the question, as to this particular use of the receiver.

Tractor sets.—It appears from the description of these sets, that they differ from the 1915 pack sets only in size, being of larger energy capacity. What I have said as to the 1915 pack sets, therefore, applies equally to these tractor sets.

24. Question. I omitted to include in the last two questions the description of the field radio pack sets, model 1912, of plaintiff's Exhibit No. 103, Signal Corps Bulletin No. 17. If you have read and understand the description of this pack set in this exhibit, will you please answer the last question, Q. 23, substituting for the 1915 model pack set and the tractor sets, therein mentioned, the field radio pack sets, model 1912, of Signal Corps Bulletin No. 17?

Answer. This 1912 pack set described in Signal Corps Bulletin No. 17 and illustrated in the diagrams accompanying it, marked 1911 *a*, and *b*, respectively, is substantially identical with the 1914 and 1915 pack sets, which I have

already considered, the differences appearing to be merely differences in capacity of the generator and details of construction. The comparisons which I have already made, therefore, applies equally to this 1912 pack set.

25. Question. Have you read the following specifications and instructions for radio apparatus, and the drawings annexed thereto, and do you understand the same?

[fol. 358] Plaintiff's Exhibit No. 39, Navy wireless specification No. 16-R-1a.

Plaintiff's Exhibit No. 40, Navy wireless specification No. 16-R-2 (receivers).

Plaintiff's Exhibit No. 41, Navy specification for portable wireless sets.

Plaintiff's Exhibit No. 44, Signal Corps specification, radio field wagon sets (dated February 19, 1916).

Answer. Yes.

26. Question. Please state in your opinion whether or not the radio apparatus described in plaintiff's Exhibits, wireless specifications and instructions, Nos. 39, 40, 41, and 44, respectively, and specified in the last question, if constructed, installed, and operated in substantial accordance with the requirements of said exhibits respectively would be substantially similar to any of the inventions of any of the claims in issue of the * * * Marconi * * * patent in suit, and, if so, which claims, giving your reasons for any opinion you may express.

Answer. *Navy specifications Nos. 16-R-1a and 16-R-2.*—These two specifications comprise in substance a revision and rearrangement of the subject matter of 16-R-1, which I have already fully considered. Specification No. 16-R-1a is devoted to transmitters and No. 16-R-2 to receivers.

Specification No. 16-R-1a: This specification requires a complete transmitter having the power circuit, including a generator, transformer, and operating key, as indicated for example in plaintiff's Exhibit No. 87 in the yellow circuit of the diagram of Wireless Specialty Apparatus Co.'s transmitter. It also requires, of course, all of the auxiliary parts for practical use, adjustment, and control. It also requires all the elements of the red circuit of Exhibit No. 87, namely, a condenser *c*, spark gap G, an inductively coupled oscillation transformer, having primary coil *d*. It further requires all the elements of the black circuit, including the secondary *d'* of the oscillation transformer, and

loading coil g, and says that the antenna and various connections will be provided by the Goverament, but it specifies the characteristics of the antenna with which the transmitter must operate, the capacity given being the minimum, since this minimum determines the maximum size of the necessary inductances.

Means of adjusting the circuits are required, and it is further insisted upon that the contractors shall supply "directions on all points necessary and desirable * * * for maintaining resonance under the various conditions of operating for wave lengths of from 300 to 2,000 meters," and this is one of the provisions which the specifications says is not subject to modification, but must be strictly complied with.

In my opinion, the transmitters furnished in accordance with this specification would unquestionably embody the invention set forth * * * in the specification of Marconi patent No. 763,772, and referred to in the transmitter claims thereof. * * *

[fol. 359] Specification No. 16-R-2: This specification relates to receivers of four different ranges, designated respectively as portable receivers, having a wave length from 75 to 1,200 meters; short-wave receivers, with a range of from 300 to 6,500; long-wave receivers, having a range of from 1,000 to 10,000 meters; and special receivers, whose range is from 5,000 to 18,000 meters. The minimum antenna capacity for which each must be constructed is specified.

As to all of these, the specifications provide for the elements shown in the black circuit of Exhibit No. 87, Wireless Specialty Apparatus Co. receiver, and for all of the elements of the red and green circuits thereof, save in the case of the portable receiver, which is not required to have the condenser h'. Other receivers are required to have this condenser, but are to be provided with switches so that it may be used or not, as desired. As I have pointed out, this condenser h' is merely an added means of adjusting the secondary circuit, particularly useful for giving refined adjustments and for increasing the flexibility by making it possible for the operator to suit the adjustment to his special need, according as greatest loudness or greatest selectivity, or some compromise between the two, best suits the purpose at hand. I note also that the specifications require that means shall be provided for the

insertion of an additional secondary inductance coil, corresponding to the coils g^2 of Figure 2 of the Marconi patent No. 763772, this being an additional tuning means. For all of the receivers except the portable receiver, a very high degree of selectivity, which implies a very high degree of accuracy in tuning to resonance between the circuits, is required, and in all of these latter receivers it is required that the secondary circuit shall be marked with the wave length resulting from given adjustments so as to facilitate this accuracy of tuning.

In view of this substantial identity of the receivers with the receiver of the Wireless Specialty Apparatus Co., diagrammed in Exhibit No. 87, it is my opinion that these receivers comply with the description of * * * the specification of the Marconi patent No. 763772, particularly recited in the receiver claims thereof.

I note this specification refers to the portable receivers in the following language (page 2):

"(e) Portable receivers shall be provided with the so-called 'untuned' secondary system; no secondary tuning condenser to be provided."

This does not mean that the circuits are not in resonance for such circuits are provided with adjustments for the purpose of putting them in resonance. It merely is a way of designating the fact that there is no secondary condenser, such as h', which the Marconi patent No. 763772 says is sometimes included in a shunt around the detector. The two forms of circuits designated by the expressions "tuned" and "untuned" are simply the circuits of the Marconi table on page 4 for tunes 2 and 1, for example, shown respectively in Figures H and G of Exhibit No. 99. In the absence of the condenser h', the coil itself is given a proper capacity so that the circuit is able to oscillate and will have a substantially correct resonant time period for a certain limited range of wave lengths corresponding [fol. 360] to each adjustment of a number of turns in the secondary coil. This matter is very well explained in the Signal Corps manual, and I quote for example from the manual of 1916, being plaintiff's Exhibit No. 92, pages 73 to 74, as follows * * *:

"The closed or secondary circuits are of two general types, called untuned and tuned, as shown respectively in Figures 61 and 62.

"In the untuned circuit there is no secondary tuning condenser, the only adjustment being in the number of turns in L_2, which is generally in steps of many turns. In the adjustment of such a set to get signals of maximum loudness, the circuits must be adjusted to resonance, and the proper coupling between them must be used. The primary circuit will be sharply tuned, but the secondary only very broadly tuned, if at all. If a close coupling is used between the circuits the tuning of both will be broad, and hence the set will have the disadvantage of being liable to severe interference. Under certain conditions, however, as in searching for an unknown station, it may be of advantage to use this coupling at first and then when the station has been picked up to loosen the coupling and to make such changes in both circuits as will give the sharpest tuning and the loudest signals. In many receiver sets of this type the so-called untuned secondary circuit is really a broadly-tuned one in which the inductance of the coil and its distributed capacity form the tuning elements. The range of wave lengths to which each step is thus broadly tuned is generally marked for each contact, thus 400 to 500 meters, 600 to 1,000 meters, etc.

"In the tuned circuit there is a variable tuning condenser, as C in Figure 62, the adjustment of which is necessary to secure the maximum loudness of signals. The secondary inductance is sometimes variable by steps and in a few cases by single turns."

In my opinion, such portable receivers would undoubtedly be tuned receivers having the two circuits in resonance by the adjustment of the inductance and of the detector, as I have already explained, and hence, would be in accordance with the receiver claims of the Marconi patent No. 763772. * * *

Specification for portable wireless set, Exhibit No. 41. This specification is accompanied by drawings marked "1815 L., sheet 1 and sheet 2, 9-22-10." Sheet 1 indicates the suggested mechanical arrangement and sheet 2 diagrammatically indicates the circuit arrangement. This circuit arrangement is identical with that of the Wireless Specialty Apparatus Co. apparatus as shown in Exhibit No. 87, except that there are no separate loading coils *a, a'*, but since the coupling in both transmitter and receiver is variable this is immaterial to the result.

In page 1, paragraph *j*, the antennae for which the apparatus is to be adapted is defined, and in paragraph 10, page 5, referred to in paragraph *j*, it is specified that the wave lengths shall be 90, 130, 170, and 210 meters. A power circuit corresponding to the yellow circuit of Exhibit No. 87, including a generator, transmitting key, and transformer, is specified. A primary oscillatory circuit, includ- [fol. 361] ing a condenser *c*, spark gap G, and coil *d'*, constituting the primary of an oscillation transformer, with four connections brought out for changes in the number of turns, is also required, and both the condenser *c* and the primary *d* are variable for changes in wave length. The oscillation transformer is required to be inductively coupled, the secondary to slide inside of the primary to permit of variation in the coupling. The secondary is required to have its inductance variable continuously from zero to maximum and connections are provided for attachment to the elevated conductor and earth wire.

. The receiver is required to include an inductively coupled oscillation transformer, the secondary to be designed so as to be as highly selective—that is, as sharply tuned and as accurately in resonance—as possible. The primary coil is required to be variable, one turn of wire at a time by means of two dial switches, one controlling 10 turns, 1 at a time, and the other controlling the balance of the turns, 10 at a time. This is the commonest arrangement in commercial wireless-telegraph receiving apparatus. The secondary coil consists of a fixed number of turns, but has the condenser marked D in sheet 2 accompanying the specification and marked *h'* in Figure 2 of the Marconi patent and in Exhibit 87, illustrating the Wireless Specialty Apparatus Co.'s receiver. It is by variation of this condenser that the highly selective tuning required is to be obtained. The detector is not specified but is required to be robust and capable of operation without loss of sensitiveness. A potentiometer and detector battery is also required, and these requirements at that date could, so far as I know, only have been satisfied by the crystal detector.

Telephones are specified as indicating instruments.

The word "resonance" does not happen to be used in this specification, but since both circuits of the transmitter and both circuits of the receiver are required to be varied in time period for a change in wave length and high selectivity is required, it is clear to one skilled in the art that

the purpose of the adjustment was to put the two transmitter circuits in resonance and to put the two receiver circuits in resonance, and when these constitute an intercommunicating system all four circuits would thus be in resonance. In referring to these circuits I of course refer to the oscillatory circuits and not to the power and indicating circuits.

It is my opinion, from this description, that the comparisons and conclusions which I have made with respect to the Wireless Specialty Apparatus Co.'s transmitter and receiver apply equally to any transmitters made under this specification, Exhibit No. 41, bearing in mind the fact that separate loading coils are not called for but are effectively combined with the oscillation transformer. In my opinion apparatus complying with the specification would necessarily embody the construction, combination, and mode of operation set forth in the Marconi patent and referred to in the claims thereof in issue.

United States Signal Corps specification, Exhibit No. 44 (dated February 19, 1916), radio field wagon set.—This specification provides for a power circuit consisting of a generator, transformer, and operating key, as shown in the yellow circuit of Exhibit No. 87, showing the Wireless Specialty Apparatus Co.'s transmitter and receiver, and also requires a primary oscillatory circuit, including spark gap, condenser, oscillation transformer primary, as shown in [fol. 362] the red circuit of Exhibit No. 87, and for a secondary circuit having the secondary of the oscillation transformer of such dimensions as will give a range of wave length from 600 to 2,000 meters when used with antennae, as specified in the specification. It is also required that the inductances shall be variable so that the transmitter shall be capable of being correctly tuned and coupled at all of these wave lengths. It is stated in the specification that the spark gap, transmitter, condenser, and key shall be furnished by the Signal Corps and that information regarding these will be furnished to the contractor. It does not provide for or require separate loading coils, such as *a, a'*, of Exhibit No. 87, but does provide that this shall be effectively included in the oscillation transformer. It is clear therefore that the transmitter built under these specifications would be substantially such a transmitter as that that I have fully considered and compared in considering the transmitter of the Wireless Specialty Apparatus Co.,

and, in my opinion, with such a transmitter as is described in the Marconi patent No. 763772 and referred to in the transmitter claims thereof.

The specifications state regarding the receiver that two receiver sets are intended to be furnished by the Signal Corps, but that the bidder's design will be considered. Each wagon set is to be provided with two receivers, one of simple rugged construction, to cover a range of from 300 to 2,500 meters and the other of larger size and greater sensibility and selectivity from 300 to 5,000 meters range. The sort of detector to be used is not specified. This information regarding the receiver is hardly sufficient to enable me to make a comparison.

27. Question. Have you read and do you understand that part of the article by Captain Bullard contained in plaintiff's Exhibit No. 81, Proceedings of the Institute of Radio Engineers, relating to the 100-kw. arc set of the Federal Telegraph Co., installed at the Arlington Radio Station; the evidence relating to this set given by Mr. Graham in his deposition herein; the description and illustration of said Federal Telegraph Co. receiving circuits contained in article 200, page 134, of plaintiff's Exhibit No. 78, Navy Manual for 1913 and 1915; plaintiff's Exhibit No. 65, contract No. 1948, dated June 30, 1913, between the said Federal Telegraph Co. and the United States for the installation of a radio station at San Pablo site, Canal Zone, and the wireless specification forming part thereof; and plaintiff's Exhibit No. 66, contract dated June 11, 1914, for furnishing certain radio equipment for said Canal Zone station, and supplemental to said contract, plaintiff's Exhibit No. 65; also plaintiff's Exhibit No. 67, contract No. 269, dated April 6, 1914; and plaintiff's Exhibit No. 68, contract No. 421, dated May 6, 1915, between the same parties for radio sets?

Answer. I have read the exhibits referred to and understand them so far as they go, but they do not in all cases make the construction contemplated clear to me.

28. Question. Please consider and explain the evidence referred to in the last question relating to these arc transmitters and the receivers of the Federal Wireless Telegraph Co., and where such evidence forms a sufficient basis [fol. 363] for comparison of such transmitters and receivers, or either of them, with those of the invention of the claims in issue of the Marconi patent, please make the

comparison and give your reasons for any opinion you may express, and where the evidence does not form sufficient basis for such comparison will you please point it out and state why you can not make the comparison or express any opinion.

Answer. *Federal Telegraph Co.'s Arlington arc transmitter.*—The Arlington arc transmitter, as described by Captain Bullard and diagrammatically indicated in Figure 14, is more simply illustrated in the diagram which I have made, using the same letters of reference as were placed by Mr. Graham upon Exhibit No. 81. It comprises an elevated conductor *f*, loading coil *g*, spark gap (not lettered), and earth connection E. Across the gap is connected a condenser *c* and a power circuit, comprising a generator *a*, protective reaction coils *y*, adjusting resistance W, and magnetic blast X. The usual measuring instruments and switches are provided, but I have omitted them from my diagram. The telegraph key *b* is connected to the inductance coil *g* and operates by changing the wave length, instead of by connecting and disconnecting the power.

In the transmitters which I have heretofore considered a charge is imparted to the antenna or a condenser and is set in oscillation by the passage of a spark across the gap, and the oscillation of current thereby set up in the antenna continues until the energy is dissipated. Thereafter another charge is imparted and the operation repeated, this taking place with a frequency depending upon the character of the source of supply, being at the present time commonly one thousand times per second. In the arc transmitter the energy is not intermittently supplied, but a generator of direct current is employed which generates the same, or substantially the same, electrical pressure at all times, and energy is therefore more or less continuously supplied to the antenna, the idea being that the waves shall not be permitted to die out, and such a transmitter is often referred to as a continuous or undamped oscillation transmitter. It is also called an arc transmitter, because the discharge across the gap appears to be continuous, as in the case of the ordinary electric arc, and it was in fact originally developed, as I understand, from such an arc. When the circuit of a suitable source is closed through a pair of electrodes and a resistance in series and then the

electrodes slightly separated, a flame or arc passes between the electrodes, and from this phenomena the familiar arc lights result. The arc is a very erratic phenomena, and although the flame appears to conduct the current it is a conductor of unusual characteristics. One of these is that its resistance is less the greater the current and greater the less the current. To utilize this phenomena for wireless telegraphy it is necessary to exaggerate these peculiarities of the arc by causing it to take place in an atmosphere of hydrogen or hydrocarbon gas. It is also found desirable to apply a blast magnet. When an arc is properly exposed to the action of a magnet, it will act as though a strong blast of air were directed upon it and may be extinguished just as one blows out a candle. Such a magnet is used in connection with the Arlington arc generator.

Precisely what the action going on within the arc is, has been, and still is—the subject of a good deal of difference of [fol. 364] opinion, and the general opinion is that various things may happen, depending upon how the operation is carried on. According to the views of some authorities, the operation of the arc transmitter is precisely the same as the spark transmitter, except that the charging of the antenna occurs very much more often, being many thousand times a second instead of only about 1,000 or less. Another view is that the oscillations are continuous, but somewhat modified, in that there are brief periods during which current is not changing and hence perfect continuity of the electric waves is broken.

In shunt with the arc of the Arlington transmitter there is a condenser *c*, and it is possible that the closed circuit containing the spark gap and the condenser is a tuned resonant circuit. Such circuits are sometimes employed with arc transmitters—in fact, always, I believe, where used for wireless telephony—and it is possible to so constitute the condenser *c* and the length of its connecting wires as to cause this to be a direct coupled tuned transformer type of transmitter of the Marconi patent No. 763772. Whether or not it is in fact such a transmitter I am unable to say, because the exhibits referred to do not inform me, and I have never personally tested this transmitter. I am therefore unable to compare it with the Marconi patent No. 763772.

* * * * * * *

Federal arc transmitters of plaintiff's Exhibits 65, 66, 67, and 68.—The transmitters of these contracts are not illustrated by drawings, nor are they fully described. It is evident that an inductance coil is to be provided for an antenna circuit to vary the wave length through wide range. I am unable to make any comparison, because the circuit arrangements are not described. I note that Exhibits Nos. 65 and 66 state:

"If it be necessary to use coupled circuits to give maximum antenna input, necessary condensers and inductances will be supplied."

This evidently refers to and contemplates the use of a closed oscillatory circuit, coupled to the antenna circuit, as set forth in the Marconi patent 763772, but whether such apparatus was furnished or not does not appear from the contract.

Exhibit No. 65 also provides that the transmitting apparatus shall be so designed that by the operation of a single switch the energy radiated may be emitted either in wave trains or continuously, as desired. The means by which this was to be effected is not described. The effect would be to enable the transmitter to send signals like a spark transmitter or like an arc transmitter at will.

How the coupled circuits referred to in the above quotation might and presumably would be used is shown in Figure 29d, on page 58, of plaintiff's Exhibit No. 78, Navy Manual of 1913, and very briefly alluded to in the text of paragraph 94, and also in Figure 62, on page 118, and [fol. 365] somewhat more fully described in paragraph 182. In this instance the transmitter is shown as provided with telephone mouth-piece instead of the telegraph key, but this does not in any way alter the general mode of operation. In my opinion, this circuit, if supplied under the contracts mentioned in question, would necessarily be adjusted to have its circuits in substantial resonance and would be such a combination as is set forth in the Marconi patent 763772 referred to in the transmitter claims thereof. Whether there is specifically a difference between the power supply or circuit-charging mechanism, the result is to furnish charges to the condenser and cause their oscillation by a discharge across the gap; and if this is done more often or more continuously, it is not a lesser but rather a greater use of the disclosures of the Marconi patent.

Federal Telegraph Co. receivers.—The specifications regarding the receiver contained in Exhibits 65 to 67 call for receiving sets, and in 65 and 66 ticker detectors are also specified. The ticker detector is a vibrating device which interrupts or varies the resistance of the indicator circuit so as to permit an indicator to respond.

The specifications of the contract are not at all descriptive of the details of the receiver, leaving it to be assumed that the receiver be furnished is the regular Poulsen receiver such as is shown, for example, in the Navy manual for 1913, plaintiff's Exhibit No. 78, in Figure 89, found on page 134 thereof and described in section 200. I here quote the description as follows:

"200. Figure 89 represents receiving circuits for continuous oscillations; it shows the receiving telephone connected across the terminals of a fixed condenser in series with the detector.

"In using undamped oscillations for wireless telegraphic purposes it must be remembered that the frequency of the oscillations themselves is too high to be heard in the telephone connected with the ordinary receiving circuit, and when the circuit at the sending station is closed all that would be heard is a slight click, so that there is no way of telling a dot from a dash. This makes it necessary to place a rapidly rotating circuit breaker in the sending or receiving circuit for the purpose of creating a buzz in the telephone at the receiving station when the circuit is closed. This circuit breaker may be placed in the sending aerial, while the sending key is placed either in the aerial or shunted around a few turns of the aerial inductance, in which case it serves merely to throw the aerial in and out of tune with the closed circuit. (Art. 164.)

"If no interrupter is used in the sending apparatus, no signals can be read at a receiving station unless the wave trains are there broken up so as to produce a buzz in the telephone. For this purpose the Poulsen ticker is sometimes used, which at the same time does away with the need of any special receiver. It consists essentially of a circuit breaker actuated by a small magnetic vibrator, kept in action by a dry cell. In this receiver the closed circuit is coupled very loosely to the aerial, and this circuit is intermittently [fol. 366] connected to a large condenser, of the order of a

microfarad, by the ticker or a slipping contact detector. (Art. 210.)

"During the time of contact the condenser becomes charged, and when the contact is broken it discharges itself through the telephone, producing a note corresponding in tone to the frequency of the ticker."

The motor-driven form of the ticker is that referred to in paragraph 210, to which cross reference is made in the above quotation. In that paragraph it is referred to as a "slipping contact detector."

"210. Slipping contact detector: In its present form this consists of a small bundle of fine wires, or a single wire resting lightly on the rim of a wheel of conducting material, which is revolved at high speed by a small motor. It is not, in general, as satisfactory as crystal detectors, but is suitable for receiving undamped oscillations (fig. 89)."

Comparing with the Marconi patent No. 763772, it will be seen that the Federal company receiver, as shown in Figure 89 of Exhibit No. 78, is identical with tune 2 of page 4 of the Marconi patent, except that it has a condenser in the antenna circuit as an additional means of tuning. Figure II of Exhibit No. 99 shows the arrangement of tune 2. The adjustable elements in the antenna circuit are the loading inductance coil, this fact being indicated by an arrow across the coil and a condenser whose variable character is similarly indicated. A fixed condenser is arranged with a switch so that it may be employed if desired. The purpose of this is to shorten the wave length of the antenna and so enable waves shorter than the natural wave length to be received while still employing the inductance coil as a tuning means. The secondary coil of the oscillation transformer is shown as nonadjustable and the secondary circuit is tuned by means of the variable condenser shunted across the coil. The detector is indicated as a ticker and the indicator is a telephone. By this means the so-called continuous or undamped oscillations produced by the Federal company's arc transmitter are received. The Navy manual does not explicitly say that the circuits are tuned to resonance with one another, but they are provided with the means for tuning and are capable of being put in resonance therefore, and the results of so doing are so superior as to make it certain that no other mode of use would be acceptable to the Government. Assuming that they are so used, the description and comparison which I have made in considering the ap-

paratus of the Wireless Specialty Apparatus Co., Exhibit 87, apply, and I will not repeat. In my opinion this Federal receiver is such a receiver as is referred to in the receiver claims of the Marconi patent No. 763772. * * *

[fol. 367] Mr. Cosgrove. Plaintiff's counsel offers in evidence the diagram of the Federal arc transmitter, produced by the witness in answer to question 28, and requests that the same be marked "Plaintiff's Exhibit No. 104, Waterman diagram, Arlington Federal arc transmitter."

29. Question. Please state whether you are familiar with the construction and mode of operation of the wireless-telegraph apparatus of the National Electric Signaling Co., which was held to be an infringement of the claims in issue herein of the Marconi patent No. 763772 in suit in the suit of this plaintiff against said National Electric Signaling Co., United States District Court, Eastern District of New York; and if so, how you became familiar with said apparatus.

Answer. I am familiar with the apparatus involved in the litigation referred to. I became familiar with it in connection with that litigation, wherein I testified on behalf of the plantiff.

30. Question. Will you please briefly describe the construction and mode of operation of the wireless apparatus of the National Electric Signaling Co., referred to in the last question, referring to any sketch or drawing you may have of the same, and state how such construction and mode of operation compare with the construction and mode of operation of the apparatus of the defendant herein, which you have considered and testified about, using as a specimen of said apparatus that illustrated in plaintiff's Exhibit No. 87, drawing of Wireless Specialty Co. apparatus, or plaintiff's Exhibit No. 95, drawing, Kilbourne & Clark type of apparatus, or any of the defendant's apparatus you have testified to?

Answer. The National Electric Signaling Co.'s transmitter and receiver are shown in the diagram which I produce, marked "National Electric Signaling system," in which the same conventions are employed and the same color scheme used as in the other drawings, showing circuit arrangements.

Thus the National Electric Signaling Co.'s transmitter has the power circuit shown in yellow, including a generator

a, key *b*, transformer *c*, arranged to furnish the power for the wireless waves by supplying electric charges. It has a red circuit, comprising a condenser X, spark gap G, oscillation transformer primary *d*, adjustable at 2. Three different forms of spark gap were employed in the different installations, one an open gap type, one the so-called quenched gap type, and the third a rotary spark gap. These are indicated on the diagram which I produce by repeating three times the primary or red circuit, using different specific conventions to denote the spark gap.

The transmitter also has the antenna circuit shown in black, comprising an elevated conductor *f*, *A*, inductance coil *g*, adjustable at 1, inductance coil *d'*, adjustable at 1', and constituting the secondary of the oscillation transformer, and an earth connection at E.

The receiver comprises an antenna circuit for receiving the waves, having an elevated conductor system *f*, A, and variable inductance coil *d'*, variable at 3, the primary of an [fol. 368] oscillation transformer, *j'*, variable at 3ª, and earth connection E. It also has a condenser *h*, which may or may not be included in the antenna, according as the switch *s* is open or closed. The receiver also has a closed conserving and detecting circuit shown in red, and comprising the oscillation transformer secondary winding *j²*, adjustable at 4, a detector T, and condensor *j³*. Across this circuit there may be connected a condenser *h'*, if the switch shown just below it is closed, this furnishing an additional adjusting means. The receiver also has an indicating circuit, shown in green, comprising an indicator R, battery B, potentiometer *u*, for adjusting the battery.

This National Electric Signaling apparatus might as a matter of fact be compared with any of the sufficiently disclosed apparatus of the defendant. As I have pointed out in my preceding answers, all of the defendant's apparatus is essentially that shown in Figures C to J of Exhibit No. 99, being the several forms or arrangements shown and indicated in the Marconi patent No. 763772, in suit.

Specifically for the sake of illustration, I compare this National Electric Signaling apparatus with that of the Wireless Specialty Apparatus Co. It will be seen that the transmitters are identical in elements and their relation to one another, except that the National Electric Signaling Co. employed in its various installations sometimes the quenched spark gap, and in other cases the rotary spark

gap, or the plain open spark gap. This being merely a matter of an improved form of spark gap, it is an immaterial detail, the transmitter having, as I am advised, been held by the court to be the transmitter as disclosed in the Marconi patent, without particular regard to the construction of the spark gap.

The receiver of the National Electric Signaling Co. is identical with that of the Wireless Specialty Apparatus Co. shown in Exhibit No. 87, save that it has the additional condenser *h* controlled by a switch so that it may or may not be employed as an additional adjusting means, and that condenser *h'* also has a switch that it may or may not employ.

The same comparison might be made as to the Kilbourne & Clark apparatus shown in Exhibit No. 95, the only additional items to be mentioned being the fact that the Kilbourne & Clark transmitter has an added means of adjustment in the red circuit of the transmitter, namely, the coil *d''*, adjustable at 3. This is merely for greater flexibility of adjustment. The only difference as to the receivers is that the condenser *h* of the Kilbourne & Clark apparatus may be placed either in the antenna directly or in parallel to a portion of it, as shown in Figure 2 of the Marconi patent, and that the condenser *h'* is permanently connected across the secondary instead of by means of a switch. These are, of course, merely matters of detail.

As in the case of the Government apparatus, in the various forms which I have discussed, the two circuits of the transmitter and the two circuits of the receiver (red and black) were in resonance with one another and transferred energy, therefore, in the same manner. The detector employed by the National Electric Signaling Co. was a crystal detector or an electrolytic detector.

Mr. Cosgrove. Plaintiff's counsel offers in evidence the diagram produced by the witness in answer to Q. 28, and [fol. 369] requests that the same be marked "Plaintiff's Exhibit No. 105, Waterman diagram, National Electric Signaling Co.'s system."

30. Question. Your attention is called to plaintiff's Exhibit No. 34, certified copy of the Marconi British patent No. 7777 of 1900. Please state how the disclosure of that patent compares scientifically with the disclosure of the Marconi patent in suit No. 763772 in respect to the inventions of the claims in issue thereof.

Answer. The provisional specification of British patent No. 7777 of 1900 is in substance an abstract of the subject matter of United States patent No. 763772. It discloses the use of two circuits at the transmitter and two circuits at the receiver, means for adjusting these circuits, and the greatly increased energy which results in the transmitter and improved selectivity in the receiver from the tuning of the two circuits together to resonance.

The complete specification is similar to the specification of United States patent, the principal difference being the inclusion therein of a larger number of illustrative examples and more drawings illustrating them.

I notice one use of terms which is contrary to American usage, namely, the employment of the term "induction coil" to designate the oscillation transformers described. The drawing and descriptive matter, however, make it clear what the meaning it.

31. Question. Please explain the nature of the inventions set forth in the Fleming patent in suit, No. 803684, as claimed in claims 1 and 37 thereof, and the way the elements and devices of said inventions function or operate, defining and explaining such technical terms, phrases, and ideas found in the patent which you have not already explained and which you may consider necessary to a full understanding of such inventions, and incorporating in your answer any drawings or sketches which may simplify your explanation of technical matters.

Answer. *Fleming patent in suit, No. 803684.*—The Fleming patent relates to what is now often known as the incandescent-lamp detector and discloses the possibility of using such a lamp by the insertion within it of another electrode other than the filament, by means of which the wireless-telegraph receiver may be connected to the interior and the indicator also connected thereto to respond to any changes produced therein. Referring to Figure 1, there is shown an incandescent-lamp bulb *a*, within which is mounted in the customary manner a filament *b*, having terminal wires *f*, *e*, led therefrom to a suitable source of current, indicated as a battery *h*. There is also within the globe a metal cylinder *c*, held in place in a suitable manner, as by wires *d*, sealed into the glass, and one of these wires is brought through the glass for connection to the wireless-telegraph receiver. The antenna of the wireless-telegraph receiver is shown at *n* and is connected

to one coil *m* of an oscillation transformer, the other end of which is connected to the earth at *o*. The secondary coil *k* of the oscillation transformer has its terminals connected by wires *j* respectively to the cylinder *c* by way of wire *d*, and to the negative terminal of the battery *h* through an indicating instrument *l*. Figure 2 shows a [fol. 370] modified circuit arrangement employing two bulbs, and Figure 3 an arrangement wherein several may be used, three being shown. These two latter figures do not show the antenna, but only the secondary coil *k* of the oscillation transformer, the primary and antenna being understood. This arrangement constitutes a very sensitive and reliable detector.

The Fleming patent, in introducing the specification, states as follows, page 1, lines 11 to 37 and 53 to 76:

"This invention relates to certain new and useful devices for converting alternating circuit currents, and especially high-frequency alternating electric currents or electric oscillations, into continuous electric currents for the purpose of making them detectable by and measurable with ordinary direct-current instruments, such as a 'mirror galvanometer' of the usual type or any ordinary direct-current ammeter. Such instruments as the latter are not affected by alternating electric currents either of high or low frequency, which can only be measured and detected by instruments called 'alternating-current' instruments of special design. It is, however, of great practical importance to be able to detect feeble electric oscillations such as are employed in Hertzian wave telegraphy by an ordinary movable coil or movable needle mirror galvanometer. This can be done if the alternating current can be 'rectified'—that is, either suppressing all the constituent electric currents in one direction and preserving the others, or else by changing the direction of one of the sets of current which compose the alternating current so that the whole movement of electricity is in one direction. * * *

"I have discovered that if two conductors are inclosed in a vessel in which a good vacuum is made, one being heated to a high temperature, the space between the hot and cold conductors possesses a unilateral electric conductivity, and negative electricity can pass from the hot conductor to the cold conductor, but not in the reverse direction. As the hot conductor should be heated to a very high

temperature—say, near to the melting point of platinum (1,700° centigrade)—it should be of carbon, preferably in the form of a filament such as is used in any ordinary incandescent electric lamp. The cold conductor may be of many materials; but I prefer a bright metal, such as platinum or aluminum or else carbon. The two conductors are inclosed in a glass bulb similar to that of an incandescent lamp, and I generally heat the carbon filament to a high state of incandescence by a continuous electric current, the electrical connection to the filament and the cold conductors being made by platinum wires sealed air-tight through the glass."

Regarding the construction of the bulb, the specification says, as follows, quoting from page 1, line 84, to page 2, line 4:

"In figure 1 *a* is a glass bulb, and *b* is a carbon filament of an incandescent lamp suitable, say, for taking a current of six to eight volts and two to four amperes. *c* is a cylinder of aluminum, open at the top and bottom, which surrounds but does not touch the filament. The cylinder *c* is suspended and steadied by platinum wires *d*, and the ends of the filament *b* are connected to platinum wires connected to the leads *e* and *f*. The platinum wires are sealed through the glass in the ordinary manner.

[fol. 371] "As a very high vacuum should be obtained in the bulb *a* and as a considerable quantity of air is occluded in the conductors, these should be heated when the bulb is being exhausted. The filament *b* can be conveniently heated by passing a current through it, while the cylinder *c* can be heated by surrounding the bulb *a* with a resistance coil through which a current is passed, the whole being inclosed in a box lined with asbestos or the like. When, as hereinafter described, the cylinder *c* is replaced by any form of conductor which can be heated by passing a current through it this method is usually more convenient than that just described."

Modifications of the construction are referred to as, for example, the cylinder may be replaced by a loop, or a number of filaments may be employed to constitute the several elements or a gridlike structure may be used. This is set forth on page 2, line 73 to line 86, as follows:

"In place of using a metal cylinder surrounding a carbon-loop filament I sometimes use a number of carbon filaments. Some of these are heated by means of an electric current and become the hot conductor of the oscillation valve and the other remains cold and form the cold conductor, or the metal cylinder may be replaced by a cylinder of meerschaum or the like having wound helically upon it a narrow ribbon of metallic foil. In those cases in which a larger alternating current has to be dealt with the hot conductor may be a rod of soft graphitic carbon held in suitable supports."

Regarding the mode of use, the specification says, page 2, lines 5 to 14, as follows:

"The carbon filament is made highly incandescent in the usual way by a continuous electric current produced by the battery *h*, the negative pole of which is connected to the wire *e* and the positive to the wire *f*. The wires *d* and *e* are connected together by a wire *j*, which completes the circuit through the secondary winding *k* of an induction coil (such as is ordinarily used in wireless telegraphy) and a galvanomiter *l*."

I note in this last quotation the use of the expression "induction coil," as meaning an oscillation transformer. This should not be confused with the same term as used to designate a source of high-tension current for the transmitter. The circuit described in the above quotation and shown in figure 1 is a well-known wireless-telegraph circuit, and this and others are used in the practical application of the Fleming invention. It will be observed that it serves two purposes in the practical use of the device: First, through the intervention of the oscillation transformer *k* it impresses upon the space between the element *c* and the filament *b* the effect of the received electric waves; second, it connects the two elements *b* and *c* with a conducting path containing an indicator *l*, and thus indicates that the effect of the electric waves has been impressed on the space, and thus the indicator is caused to indicate the receipt of the signals and it becomes possible to read them. Regarding the operation, the specification states as follows on page 2, lines 18 to 27:

"The arrangement described above operates as an electric valve and permits negative electricity to flow from the hot carbon *b* to the metal cylinder *c*, but not in the reverse [fol. 372] direction, so that the alternations induced in the coil *k* by the Hertzian waves received by the aerial wire *n* are rectified or transformed into a more or less continuous current capable of actuating the galvanometer *l* by which the signals can be read."

Why the device operates in the manner set forth in the patent or what the particular natural mechanism of the space within the bulb may be which secures the result is not certainly or clearly understood, but Fleming sets forth the construction and the apparent functioning of the apparatus in the above statement.

As to the means of indicating, associated with the devices, the specification says as follows on page 2, lines 118 to 123:

"When I specify in my claims 'means for detecting a continuous current,' I intend to include any instrument for detecting such a single unidirectional pulsating current or two such unidirectional pulsating currents flowing in opposite directions."

I note that the term "continuous current" here employed meant at that time simply a current flowing in one direction, whether constant in strength or not. Recently by a convention the term has been reserved to apply to a current flowing always in one direction and substantially constant in strength, while the term "direct current" designates a current in one direction, whether constant or pulsing or otherwise variable.

Claims 1 and 37, to which my attention is called, read as follows:

"1. The combination of a vacuous vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, and a circuit outside the vessel connecting the two conductors."

"37. At a receiving station in a system of wireless telegraphy employing electrical oscillations of high frequency a detector comprising a vacuous vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, a circuit outside of the

vessel connecting the two conductors, means for detecting a continuous current in the circuit, and means for impressing upon the circuit the received oscillations."

32. Question. Are you familiar with the operation of and have you used detectors as described in the Fleming patent in suit? And if so, what was the structure of these detectors and from whom did you obtain them?

Answer. I am familiar with the use of these detectors of the Fleming patent and have personally used large numbers of them. In structure these have differed from one another in various particulars, such as the shape and position of the cold element and the shape, position, and material of the hot element. I have used considerable numbers, substantially identical with the construction shown in the Fleming patent and others, in which the cold element took the form of one or two plates, parallel to the filament or facing it and at right angles to it. I believe that all that I have used have been obtained from the plaintiff Marconi company. I have used them, both for the receipt of messages and also for the various tests and experiments I have made with them. I have found them both sensitive and reliable in practical use.

33. Question. Have you used and are you familiar with the detectors of the type known as the PN audion referred [fol. 373] to in plaintiff's Exhibit No. 71, contract with the Radio T. & T. Co., of March 5, 1914; also the DeForest PN audion, used by the Navy, of plaintiff's Exhibit No. 82, and the diagrams and connections of such exhibit as illustrated in plaintiff's Exhibit No. 83; the "ultra audion" of the type called for by plaintiff's Exhibit No. 74, contract between the Radio T. & T. Co. and the Navy as illustrated in plaintiff's Exhibit No. 84, official instructions for use of "ultra-audion," and the amplifiers illustrated in plaintiff's Exhibit No. 85, drawing of audion amplifier used by the Navy, and referred to in plaintiff's Exhibit No. 72, contract of Radio T. & T. Co.? And if so, will you please state when and under what circumstances you became familiar with those types of detectors and used the same?

Answer. The several trade names used in the question, such as PN audion, ultra-audion, and audion amplifier, all refer to the same thing, namely, an incandescent-lamp detector used with various adjustments and circuits. I do

not remember when I first became familiar with these, but I have owned one of the PN audions, substantially like plaintiff's Exhibit No. 82, for some years and have made much use of it and I have used it in all of the ways indicated by the several trade names of the question and various others as well. I have owned numerous bulbs, known as audions, and have used them with various other apparatus than the particular PN audion box to which I have just referred.

I also became familiar with the several types of audion referred to in the question in the suit of Marconi Wireless Telegraph Co. *v.* the DeForest Radio Telephone & Telegraph Co. in the United States District Court for the Southern District of New York, brought for the infringement of this Fleming patent. I testified on behalf of the plaintiff in this case, and I am advised that these types of audions referred to in the question were held to infringe claims 1 and 37 of the Fleming patent in suit. I recognize Exhibit No. 82 as the sample which was in evidence in that case as plaintiff's Exhibit No. 2 therein, and also the bulbs as similar to the bulbs which were in evidence in that case, one apparently being the same one as was there in evidence.

34. Question. Please compare the construction and operation of the invention of the Fleming patent in suit, as described in claims 1 and 37 thereof, with the construction and operation and use of (1) the De Forest PN audion detector, (2) the "ultra-audion" detector, and (3) the audion amplifier used by the Navy as set forth in Mr. Graham's deposition and illustrated in plaintiff's Exhibits No. 83, drawing, PN audion, No. 84, official instructions for use of ultraaudion, No. 85, drawing of audion amplifier, and as exhibited in plaintiff's Exhibits No. 82, De Forest PN audion, and also as referred to in plaintiff's Exhibits Nos. 71, 72, and 74, contracts between the radio T. & T. Co., and the United States Navy. In answering this question, you may make use of any other exhibits and drawings you deem necessary!

Answer. Exhibit No. 82, defendant's PN detector, is simply a box fitted with suitable mountings for two incandescent lamp detectors, sold under the trade name "audion" and provided with suitable connections and binding posts, switches, and the like for using either one of the bulbs at will after the manner indicated in the diagram, plaintiff's Exhibit No. 83, or otherwise as desired.

[fol. 374] The incandescent lamp detectors which form part of this Exhibit No. 82 are simply small incandescent lamps, each of which is provided with two filaments and two additional elements, one of which is a bit of wire bent back and forth to form a sort of grid, placed parallel with the plain filaments and about one-sixteenth of an inch away from it, and the other of which is a small metal plate, placed parallel with the grid and about one-sixteenth of an inch away from it. The two filaments are provided so that if one burns out the other may be used and the spare filament is not normally connected. One of the bulbs, namely, that one which has upon it a tag marked "De Forest standard audion bulb" and initials "W. C. B., Oct. 13, 14," is a so-called standard audion bulb, having a tantalum filament, while the other, having an additional tag marked "dup-A-4," is identical with the other, except that the filament is the so-called Hudson filament, being, as I understand, a tungsten filament with a little particle of tantalum in the center. The circuits of the box, Exhibit No. 82, are shown in the diagram marked "Simplified circuit of PN detector." The upper figure shows the circuit arrangement of the box itself and the several letters thereon such as "R A" and "R E" are the markings found on the box itself. The lower diagram shows the complete wireless telegraph circuit of the box when one bulb is in use. The heavy, black line incloses so much of the circuit arrangement as belongs to the box. This lower diagram is substantially identical with Exhibit No. 83, introduced by Mr. Graham.

Comparing the PN audion as connected for use, namely, as shown in plaintiff's Exhibit No. 83, copy of which is inserted opposite, with the Fleming patent, it will be seen that there is in each case an incandescent lamp detector, connected to a wireless telegraph circuit. The particular details of the wireless telegraph circuit itself I assume are immaterial and it is sufficient to note that in each secondary of the oscillation transformer (marked j^2 in Exhibit 83 and k in the Fleming patent), has one end connected to the wire leading to one terminal of the incandescent filament and the other leading to a cold element within the bulb, whereby the oscillations produced by the receipt of the electric waves are impressed upon the space between the cold element and the filament. In each, also, the effect of the receipt of these oscillations is indicated by an indicator marked R in Exhibit 83 and l in the Fleming patent. In the

particular circuit which Fleming has chosen, the two functions of impressing the oscillations on the space and conducting the indicating current to the indicator, are performed in a single circuit by means of a single cold element. In the case of the lamp called the audion, these two functions are divided and the cold element is divided into two to one of which, marked G in Exhibit No. 83, is assigned the function of impressing the oscillations upon the space, and to the other of which, marked P, is assigned the function of completing the circuit of the indicator and indicating the result of the oscillations. These two forms of circuit I may say are very well-known equivalent forms. It will also be noted that in the arrangement of Exhibit No. 83 there is a local battery B^2, in circuit with the indicator and there is a condenser 3 in the wire leading to the oscillation transformer.

[fol. 375] For greater ease in comparing these and showing exactly what the differences are I produce a diagram marked "Fleming and De Forest compared." The left-hand one of these figures substantially reproduces Figure 2 of the Fleming patent in slightly more conventionalized manner and the right-hand figure similarly represents Exhibit No. 83, somewhat more conventionalized. The splitting up of the cold element and the combined detecting and indicating functions of Fleming's arrangement into two cold elements and circuits in the PX audion arrangement is here clearly shown.

In the Fleming patent no local battery is employed in the indicating circuit, the only battery being the heating battery. In the PX circuit, a battery B is shown. Such a battery may also be used in the Fleming valve circuit, or the Fleming valve may be used in the PX circuit. My practical use of these valves of the Fleming patent shows that some of them are very much improved by the use of a battery and that others are not.

It will be seen that the audion is, like the Fleming valve, an incandescent lamp detector having an incandescent lamp filament, mounted in a highly evacuated glass globe, that there is mounted therein in addition to the filament, a plate and a wire grid with terminals brought out for connection to the exterior circuit. The separation of Fleming's cold conductor into two does not in any way alter the valvelike action, which permits the flow of negative electricity from a hot filament to the cold element but not in the

reverse direction, as described by Fleming, and the device acts in similar manner to detect the receipt of wireless signals. Of course, when the valve of the Fleming patent is used without a battery, in circuit with the indicating instrument the effect of the received signal is to produce a current in the indicator to which the latter can respond. If a battery is used, the effect is to produce a variation in the battery current flowing. Similarly in the PX audion arrangement, wherein the local battery is employed the effect of the receipt of a signal is to produce a change in the current flowing to the indicator, which is observed by the operator either orally or visually.

In my opinion, the De Forest PX audion is such an incandescent lamp detector as is disclosed in the Fleming patent, being substantially such a structure and being associated with the wireless telegraph circuit, substantially as shown in the patent and referred to in claims 1 and 37 thereof.

Exhibit No. 71, referred to in the question, I have already considered in connection with the Marconi patent. I note that in item 5 the letter attached to the contract in this exhibit, states that the audion, PX type, will be furnished if desired by the bureau. I understand that the box and bulbs as illustrated in Exhibit No. 82 are there referred to.

Mr. Cosgrove. Plaintiff's counsel offers in evidence the diagrams and drawings referred to by the witness in this answer to Q. — and requests that the same be marked "Plaintiff's Exhibit No. 106, drawing, simplified circuits of PX detector," and "Plaintiff's Exhibit No. 107, drawing, Fleming and De Forest compared."

[fol. 376] Witness (continues). I produce a leaflet which purports to give instructions for the type RJ4 audion detector, this being the same sheet which was in evidence in the case of this plaintiff against the DeForest Radio Telephone & Telegraph Co., above referred to, and was accepted as instructions in the operation of the exhibit PX audion detector, which was in evidence and which is here in evidence as Exhibit No. 82. My understanding is that it was issued as such by the Radio Telephone & Telegraph Co. upon the original purchase of Exhibit No. 82. It gives the circuit diagram and instructions for connecting and operating. These instructions caution against using too much local battery and say that when enough local battery is used

to produce a blue glow the bulb loses its sensitiveness. This means that the vacuum in the audion bulb is high and that the bulb must not be used at any local battery voltage which is great enough to excite or ionize any residual gas contained therein, as to do so would mean to lose the sensitiveness of the bulb.

Mr. Cosgrove. Plaintiff's counsel offers in evidence the instructions referred to and requests that the same be marked "Plaintiff's Exhibit No. 108, audion instructions."

Defendant's "ultra-audion."—The so-called ultra-audion is simply the audion with its circuits slightly modified. That this is so is clearly stated in plaintiff's Exhibit No. 78, Navy manual for 1915, page 144:

"When connected for receiving continuous oscillations it is called the 'ultra-audion.' "

This circuit enables undamped oscillations to be more easily received and also more easily permits the audion to oscillate and therefore increases its sensitiveness.

Exhibit No. 84, official instructions for use of ultra-audion, describes and illustrates how the audion box, such as the PX detector box in evidence, is to be connected in order to have the ultra-audion connection, and it shows that the receiving tuner is simply to be connected to one of the binding posts marked G, through a variable condenser and to one of the binding posts marked R, instead of to the post marked R A and R E. I produce a diagram, which shows in simplified form this Fig. — of Exhibit 84. It will be seen that it differs only in that a variable condenser is substituted for the fixed condenser of Exhibit No. 83 and that the other end of the oscillation transformer connects to the plate end of the telephone circuit. There is also a condenser around the local battery and telephone. The mode of operation of the bulb in this connection is not different from that in the other or PX connection, but it is easier in this circuit to bring about the so-called oscillating condition. In this condition the current in the indicator circuit becomes oscillating in character, and this condition will be continuously maintained if the adjustment is correct. The flow of this oscillating current increases the sensitiveness of the bulb as a detector and also enables it to effectively alter the received frequency of undamped oscillations, which are then detected in the regular way. The precise details of

the operation of these vacuum valves are not fully understood, and my statements are therefore to be regarded as [fol. 377] merely a general indication of what happens, rather than a precise definition of the way it happens.

Contract, Exhibit No. 74, refers to ultra-audion detectors and bulbs therefor, also receiving cabinets therefor. The bulbs called for are two sizes, namely, 6-volt bulbs, which means that the incandescent filaments can be properly heated from this 6-volt battery, and 12-volt bulbs, which means that a battery of 12 volts is required for the heating.

In my opinion, these ultra-audion detectors called for in this contract are such detectors as are disclosed in the Fleming patent and operating in substantially the same manner. They are also used in such combinations as are referred to in claims 1 and 37.

I may note that the so-called oscillating state is not a peculiarity of incandescent lamp detectors, although they are particularly convenient for this work. Any detector which is also able to control the local battery current so as to amplify the received energy is capable of being put in the oscillating condition, this being done by transferring part of the energy of the battery circuit back to the controlling circuit to keep the latter continuously excited. In other words, the continuous repetition of the detecting function is the so-called oscillating state, and a detector in the oscillating state may be said to be continuously detecting, the fact that it is detecting.

Mr. Cosgrove: Plaintiff's counsel offers in evidence the diagram referred to above and produced by the witness and requests that the same be marked "Plaintiff's Exhibit No. 109, Waterman diagram, defendant's 'ultra-audion.'"

Defendant's audion amplifier.—The arrangement of the audion, which is called the amplifier, is shown in Mr. Graham's drawing, Exhibit No. 85, inserted opposite. This drawing shows the so-called three step amplifier, being three bulbs arranged tandem, each one to receive and amplify the signals produced by the one in advance. If the right-hand bulb and its circuit connections were simply omitted, the remaining portion of the diagram would show the so-called two-step amplifier, and if the two at the right were omitted a one-step amplifier would remain. In the actual instruments, as I am familiar with them and as indicated by Mr. Graham in Exhibit No. 85, either one, two,

or three steps may be employed by connecting the indicator R at R^2 for a two-step amplifier or R^1 for a one-step amplifier. I note that Mr. Graham's diagram does not show the complete circuit arrangement. A complete diagram, however, is given on page 143 of plaintiff's Exhibit No. 78, Navy manual for 1915.

This diagram I produce, attaching to it letters of reference. In this diagram A is the vertical wire, j^1 the primary of the oscillation transformer, j^2 the secondary thereof, and h the tuning condenser. Three detector bulbs T, T^2, T^3, together constitute the detector, R being the telephone indicator. In this particular figure the first bulb T^1 receives the signal in the ordinary way, which I have considered in considering the PX audion, and which is shown in Exhibit No. 83. The signal so received may be too faint to be readable, and in that case the telephone or indicator of Exhibit No. 83 is replaced by a transformer 1, to which [fol. 378] is connected a second bulb, as shown in the sketch opposite. If the signal is still too weak, a second transformer 2 is inserted, to which another bulb T^3 is attached in the local circuit of which the telephone R is placed, or, if need be, still another bulb may be added until the resulting sensitiveness of the group is sufficient to give the desired loudness of signal. Referring again to Mr. Graham's diagram, Exhibit No. 85, the two left-hand terminals X Y correspond to X Y on the diagram just reproduced, being the two terminals which would be connected to the receiver in place of the telephone of Exhibit No. 83.

I note that Exhibits 72 and 73 are contracts for the supply of amplifiers of this audion-detector type. I also note that Exhibit No. 86 is a bulletin of the Radio Telephone & Telegraph Co., illustrating on page 190 the PX type of audion detector and on page 192 the audion amplifier detector, having three bulbs corresponding to Mr. Graham's diagram, Exhibit No. 85. I may say that in the case of this plaintiff against the DeForest Radio Telephone & Telegraph Co. a combined ultra-audion and amplifier instrument, in appearance exactly like the cut on page 192 of Exhibit No. 86, was before the court, the first or lower bulb being provided with circuit connections, so that all three bulbs were arranged exactly as shown in Figure 88^a of Exhibit No. 78, which I have just produced, or the first bulb could be connected in the so-called ultra-audion manner, the other bulbs being connected as shown in the last-

mentioned diagram. All of these arrangements, namely, the PM detector, the ultra-audion detector, and the audion amplifier detector, were before the court in that case, and, as I understand, were held to be infringements of the Fleming patent No. 803684 in suit.

The operation of a tandem series of bulbs is the same substantially as that of a single bulb, that is to say each successive bulb repeats the action of the one before it. Thus, the first bulb T^1 (referring to fig. 88*a*), detects the receipt of an electric wave with the result that a variation of current is produced in the circuit of its local battery B^2. This variation of current will consist of a variation of the normal current flowing through the battery, both at the same rate as the variation of the received signal, and also at the lower rate corresponding to the group frequency or spark frequency of the signal. These variations pass through the transformer I and are handed on to the next bulb, which does exactly the same thing, but if it is a bulb capable of amplifying, the variations produced in its local battery circuit will be larger. These larger variations are passed on to the next bulb, which in turn will amplify and thus by successive repetitions variations great enough to be easily audible in the telephone or to be loud enough for the purpose desired may be secured. It is, of course, the fact that a local battery is used that enables these repetitions to be made successively stronger.

It should be understood that, as a matter of fact, not all bulbs, whether they have one cold element as shown in defendant's patent, or two, as in the so-called audion, are able to work efficiently enough to produce an amplification. The bulbs which will amplify have to be selected by trial.

In my opinion, these audion detectors, referred to in the several exhibits, are incandescent lamp detectors, as set [fol. 379] forth in the Fleming patent and referred to in the claims thereof and the particular uses or modes of connection merely illustrate ways of using them to receive wireless-telegraph signals, as set forth in the Fleming patent.

34½. Question. In your last answer you have referred to and quoted from paragraph 208, page 143, of plaintiff's Exhibit No. 78, Navy manual for 1915. What is your opinion as to the so-called differences between the audion and Fleming valve and the alleged additional advantages attributed to the former, as set forth in that paragraph?

Answer. The paragraph 208 of Exhibit No. 78 inquired about is merely comparing the use of the incandescent lamp detector used without a local battery with its use with a local battery. The great drawback to the use of a local battery is that the batteries deteriorate and give a very large amount of trouble. The Fleming valve literally as shown in the Fleming patent is an excellent detector used with or without a local battery and when used without a local battery it avoids the nuisance of maintaining and adjusting these batteries. Further, until the last few years, there have not been available small dry batteries convenient for the purpose. The incandescent lamp detectors have been used both with and without the local batteries. Either the two element bulbs shown in the Fleming patent or the three element bulbs may be used without a battery or either may be used with a battery. Paragraph 208, under consideration, merely compares the "Fleming valve" as used without a battery with the audion as used with a battery. Of course, no detector used without a battery can amplify, because there must be a local source of energy to give the increased signals, but either the two- or the three-element bulb can be used to amplify when used with a local battery. When, therefore, paragraph 208 states "The audion has the further advantage over the valve, in that the telephone can be replaced by the primary of a transformer, the secondary of which is connected to another audion, with the result of amplifying the signals produced (see fig. 88*a*)" it is referring to a result obtained by the use of the incandescent lamp detector with a battery.

I may note that individual bulbs, whether two element or three element, are found to differ greatly in sensitiveness even though apparently of the same construction. The reason for this variation is not known, but it is true of either form and is not the result of definable differences in construction.

Mr. Cosgrove: Plaintiff's counsel offers in evidence the Figure 88a from the Navy manual of 1915, referred to in the answer to Q. 33, and requests that the same be marked "Plaintiff's Exhibit No. 110, Figure 88a, amplifying audion."

35. Question. Have you examined and do you understand the construction, arrangement of circuits, and operation of

plaintiff's Exhibit No. 28, Fleming valve receiver, and plaintiff's Exhibit No. 29, Fleming valve or bulb forming part of said receiver?

Answer. Yes; I examined the exhibits referred to on April 16 of this year and traced the circuits of Exhibit No. 28.

36. Question. What relation does the construction, arrangement of circuits, and operation of plaintiff's Exhibits Nos. 28 and 29, referred to in the last question, bear to the invention of the Fleming patent, as described in the specification thereof and recited in claims 1 and 37 thereof?

[fol. 380] Answer. Exhibit No. 28, together with the bulb 29, constitutes an incandescent-lamp detector and wireless-telegraph receiver, such as shown in the Fleming patent, substantially as shown in Figure 1. I have made a diagram, * * * illustrating the apparatus arranged for use, and I have inclosed in dotted lines that portion, which is contained within the exhibit itself. In the diagram as I have drawn it, *f* A is an elevated conductor, connected to the primary *j'* of an oscillation transformer, the other end of which is connected to earth. The two binding posts for connection to antenna and earth are found on the sides of the box, marked respectively "aerial" and "earth." The secondary circuit consists of a secondary coil j^2, for the oscillation transformer, a variable condenser *h*, which is at the left of the front of the instrument and comprises two slidably mounted brass tubes, by which it may be recognized. It also includes a connection leading to the binding post mounted on a rubber pillar on the front of the box to which the wires connected with the cold elements of the bulb are to be attached and it has sockets for the mounting of the two bulbs and a switch, which I have indicated at S, for determining which one of the bulbs shall be used. The other terminal of the secondary circuit is connected through two condensers j^3, j^4, to the negative terminal of the battery B^1. The indicator R is connected around the condenser j^4. It will be seen by comparing with Figure 1 of the Fleming patent that the circuit arrangement, when bulb is in use, is identical with that shown in the Fleming patent, except for the addition of the adjustable condenser *h*, which is a means of tuning and the insertion of the fixed condenser j^3 and j^4, which are merely variations of the details of the circuit evidently found useful.

Mr. Cosgrove: Plaintiff's counsel offers in evidence the sketch produced by the witness in answer to the last question and requests that the same be marked "Plaintiff's Exhibit No. 111, Waterman sketch, circuit of Exhibit 28, Fleming valve receiver."

37. Question. Your attention is called to plaintiff's Exhibit No. 77, certified copy of Fleming British patent No. 24850, of November 16, 1904. Please state how the apparatus disclosed in the provisional specification of that patent and its operation compare with the disclosure of the Fleming patent in suit No. 803684, as claimed in claims 1 and 37 thereof.

Answer. The provisional specification of the patent referred to makes practically the same disclosure as the Fleming patent in suit, No. 803684, as I understand the same.

38. Question. Please compare and point out the relation, if any, in your opinion, between the construction, arrangement, and operation of the wireless-telegraph receiving circuits of the "N audion, "ultra-audion," and audion amplifiers, used by the Navy, and which you have considered in Q. 33, and the construction and operation of the inventions of Marconi patent No. 763772, as recited in the receiver claims thereof in issue herein, referring to any exhibits already introduced herein and giving your reasons for any opinion you may express.

Answer. The only information which I have as to the wireless telegraph circuits employed when the audion is [fol. 381] used by the Navy as the detector, whatever the specific mode of use may be, is that found in Exhibits 83 and 84, and that indicated by the diagram on page 143 of Exhibit No. 78, Navy manual of 1915. Exhibit No. 83 shows specifically the circuit arrangement of the Wireless Specialty Apparatus Co. I-P-76 receiver, and Exhibit No. 84 appears to state that it is the I-P-76 receiver, which is used with the ultra-audion detector. As to both of these, therefore, I have already made the comparison and have pointed out that this I-P-76 receiver is such a receiver as is referred to in the Marconi patent No. 763772, and particularly as recited in the receiver claims thereof. The diagram on page 143 of Exhibit No. 78 seems also to be intended to illustrate an antenna circuit, including one coil of an oscillation transformer and a secondary circuit, whose induc-

tance and capacity are both variable for the purpose of tuning the two circuits to resonance with one another and with the received signals. So, understanding the circuit, it evidently is also such a receiver as is referred to in this Marconi patent and particularly pointed out in the *receiver* claims thereof.

Mr. Cosgrove. Plaintiff's counsel gives notice that on the issues herein of validity and infringement or unlawful use of the inventions of the claims in issue of the patents in suit, plaintiff relies upon the defendant's wireless apparatus, considered in the foregoing deposition of Mr. Waterman, as samples or specimens of said infringement or unlawful use without, however, waiving or prejudicing the plaintiff's right to recover on the issue of compensation for infringement or unlawful use, damages, and profits, or compensation not only on such sample apparatus, but on all wireless apparatus of substantially the same type or character made and used or installed and used by the defendant since June, 1910, including the wireless apparatus called for in all of the exhibit contracts offered in evidence herein.

(Direct examination closed.)

Deposition of Geo. H. Clark, for claimant, taken at New York, N. Y., on the 11th day of December, A. D. 1922, and subsequent dates.

* * * * * * *

Direct examination.

By Mr. Peters:

George H. Clark deposed and said that his name is George H. Clark; that his occupation is that of radio engineer; that he is 41 years of age; that his place of residence is 38 Washington Square; that he has no interest, direct or indirect, in the claim which is the subject of inquiry in said cause; and that he is not related to the claimant.

And thereupon the said George H. Clark was examined by the counsel for the claimant, and in answer to interrogatories testified as follows:

1. Question. What practical experience have you had in radio work?

Answer. I am a graduate of the Massachusetts Institute of Technology in electrical engineering, graduating in 1903, [fol. 382] and have been continuously engaged as a radio engineer from that time until now. From 1903 to 1908 I was with the Stone Telegraph & Telephone Co., a radio company in Boston, Mass., engaged in design and research work. From 1908 until 1919 I was radio engineer with the United States Navy, stationed at Washington, D. C. I was first designated as Government inspector of wireless-telegraph stations and later as expert radio aid. From the very first of my work in Washington I was adviser in technical radio matters to the officer in charge of the radio division of the Bureau of Steam Engineering, Navy Department, Washington. My work took me to practically every station of the Navy system and to very many ships. One duty which I performed exclusively up to 1917 and continued in with assistance thereafter was the preparation of the specifications for all radio apparatus which the Navy purchased. I am familiar with every type of set, both transmitting and receiving, that the Navy obtained between the dates 1908 and 1919. I was also in close touch with the Signal Corps headquarters at Washington, and have some knowledge of the Signal Corps radio apparatus. In June, 1919, I resigned from the Navy and went with the Marconi Wireless Telegraph Co. of America, and am now engaged with the Radio Corporation of America.

2. Question. Please enumerate the different types of radio apparatus which the Government had manufactured for it during the period from July 1910 to 1919, when you left the service, and in this connection state approximately when the different types were purchased and used and how they operated.

* * * * * * *

Answer. All the radio apparatus which the Navy Department had made for it or which it made itself during the period referred to was made according to specifica-

tions which I drew up. These specifications were the result of conferences with all manufacturers, modified to meet military requirements. I was officially ordered to the various manufacturing plants to observe the progress of manufacture, and such apparatus as was delivered at the Washington Navy Yard was directly under my observation while it was being tested for acceptance.

In addition to this I myself have used every type of apparatus that the Navy purchased, with the exception of airplane transmitters in service use. As a result of this close contact with the Navy apparatus I divide the Navy radio apparatus purchased during the period referred to into three general classes—transmitters, receivers, and auxiliary apparatus. In subdividing the various classes into their chief subclass I will follow the terminology which is used in a publication by the Government Printing Office, Washington, D. C., entitled "Hearings before the Committee on Military Affairs, House of Representatives, Sixty-seventh Congress, first session, Monday, May 23, 1921," the subject of the hearing being stated as "Radio patents, settlement of claims against Government for use of radio patents during the World War." I shall refer to this as the "Patent board's report" in further reference.

[fol. 383] The division of apparatus given on pages 27, 28, and 29 of this report is excellent, and I will therefore follow it. Transmitters are divided into spark, arc, alternator, and vacuum-tube types. The spark type consists of a number of forms, the oldest of which is the "open-gap" type.

One. Open-gap transmitters have spark gaps of various types, the earliest forms consisting of two fixed electrodes. A number of the sets in use in 1910 were of this type, but I do not think that any were purchased after that time. Around 1910 an open-gap of the rotary type, mounted on the alternator shaft and designed so that the spark gap moved synchronously with the alternator, were purchased. These were from the National Electrical Signaling Co. In 1911 or 1912 purchases of sets with nonsynchronous rotary gap, supplied as auxiliaries to the quenched gap, to be described later, were made. Every quenched gap set, practically, had an auxiliary rotary gap. Whereas this rotary gap was originally intended for breakdown use, during the World War it was found necessary to use the rotary gap

entirely. The purchase of these sets with open gap of the nonsynchronous type continued down to the date when I left the Navy in 1919. I have prepared a drawing, which is headed "Typical transmitter with rotating gap." This drawing was made from an original sketch of mine, and I have chec d it as being correct. The lettering of the parts of this sketch corresponds with the lettering, for example, in claimant's Exhibit No. 87, which shows a Wireless Specialty Apparatus Co. transmitter. The only difference is that the quenched gap G in Exhibit No. 87 is replaced by a nonsynchronous rotary gap in my sketch, here offered. The operation of the transmitter and the function of the various parts, as well as the adjustment to any wave length, is the same as that which has been previously referred to by one of the witnesses in this case, Langley, whose testimony I have read, and the only difference in adjustment is one of degree of coupling. Langley's description of the adjustment of a quenched-gap set is correct and applies equally to the rotating-gap set which I am here describing.

Two. The second type of spark transmitter is the quenched gap. These sets were manufactured for the Navy and came into use around 1911 and have been used continuously up to 1919. These sets have been described by previous witnesses, namely, Langley, Weagant, and Graham. I am familiar with all the types of apparatus which they have described, and in some cases have seen the identical apparatus to which they refer. The Wireless Special Apparatus quenched-gap transmitter is correctly shown in schematic diagram in plaintiff's Exhibit No. 87, and the description of the parts and of the method of adjustment and operation by Langley, whose deposition I have read, is correct. I have also examined the schematic diagrams and read the testimony regarding the Wireless Improvement Co., Simon, Lowenstein, National Electrical Supply Co., and Kilbourne & Clark, and I find them all correct.

Quenched-gap apparatus was supplied to the Navy by other companies than those referred to, but the schematic diagram of circuits and the operation is the same as that described.

Three. Transmitters with pure impulse excitation were supplied to the Navy by a number of companies, including Cutting and Washington and others, and I have seen and used this apparatus.

[fol. 384] Four. Spark sets with vacuum-tube excitation are sets originally designed for spark work and modified afterwards so as to be used with vacuum tubes. A few of these sets were changed over prior to my leaving the Navy in 1919.

The next great division of Navy radio apparatus is receivers.

Five. A large number of the receivers purchased by or made by the United States Navy were arranged with terminals so that any form of detectors could be used. Some of these have the crystal detector mounted on the panel, and have binding posts for other detectors which could be substituted externally. Other types had no detector at all with the set. All these receivers were fitted with feed-back coil. I have prepared a drawing which is marked "Receiver arranged with terminals for any form of detector." This drawing was made from a sketch of mine, and I have checked it as being correct. It shows a receiver with two-coupled circuits, inductively coupled, which was the standard type adopted by the Navy. The primary circuit consists of a primary coil j^1, with a contact arm 3, whereby the inductance could be varied. In series with this is a variable condenser h^1, shown schematically in the series connection only, although in many receivers switching mechanism was provided for putting this condenser in parallel with the primary coil j^1. The primary circuit is fed from an antenna f with down lead A, and on its other side connected to ground E. The secondary circuit consist of a coil j^2, inductively related with the coil j^1, and a variable condenser h^2. In practice loading inductances for use in both circuits were used, but are here omitted in order to simplify the drawing. The primary circuit f-A-h^1-j^1-3-E is in service use adjusted so as to be in resonance with the incoming wave, and the circuit j^2-h^2 with such additional capacity as may be offered by external detector and other apparatus is adjusted to be in resonance with the incoming waves. Hence the two circuits are tuned to the same period. From the terminals of the secondary condenser h^2 wires are led to two external binding posts, shown on the drawing as RA and RE, these being the actual letters employed on many of the receivers. From these terminals connection could be made by standard circuit to a crystal detector system, a vacuum tube, a ticker, or any other detector. A coil shown

as j^3 is in inductive relation with the secondary coil j^2, the coupling being adjustable. This coil is brought out to two external binding posts marked "Tickler." This coil is used in the plate circuit of a vacuum-tube detector when regeneration or oscillation of the detector are required. These receivers were bought by or manufactured by the Navy, being approximately the first of 1915, and receivers of this type were obtained up to 1919.

Six. The next type of receiver is the type in which the vacuum tubes were located in the receiver itself. The first type of this receiver was that obtained by the Navy from De Forest in the middle of 1914. These De Forest receivers were of the "ultra-audion" type, and were used constantly in the oscillating state. Under working conditions the vacuum tube was always oscillating. Not very many of these sets were obtained. The schematic diagram showing the circuit for this type of receiver is shown in plaintiff's Exhibit No. 109, which I have examined and find correct. I have operated these receivers personally and am familiar with the diagram. This is the receiver which the patent board's report refers to as "Receivers having built-in ac- [fol. 385] commodations for vacuum tube, arranged for oscillations only."

Seven. Receivers having the vacuum tube built into the set were also purchased in which provision was made for both oscillations and regenerations. This means that by suitable adjustments, particularly of the tickler coupling, it was possible to use a vacuum tube in the regenerative state, obtaining thereby regenerative amplification without the tube passing into oscillation. By further adjustment, such as the tickler coupling, the tube could be made to oscillate if desired. Large numbers of these receivers were purchased and made by the Navy, and since Washington Navy Yard was the yard to which all receivers and detectors were assigned I was particularly well acquainted with these types. I have prepared a drawing headed "Vacuum-tube receiver, arranged for both oscillations and regeneration," which shows schematically the wiring of this type of receiver. This sketch was made from my original pencil sketch and I checked it as being correct. The primary and secondary tuned circuits, the antenna and ground, and the tickler coil serve the same function as, and are similarly lettered to, the receiver shown in my drawing

headed "Receiver arranged with terminal for any form of detector." Continuing with the drawing here produced a vacuum tube P is shown, with its three elements P for plate, G for grid, and F for filament. This tube is mounted in an appropriate socket in the receiver. One terminal of the secondary resonant system passes through a grid condenser h^3, with a grid leak L around it, and thence to the grid G of the vacuum tube. The other side of the secondary resonant system connects to one terminal of the filament F. The plate P connects through the tickler j^3 to a receiver R, which may be an ordinary telephone receiver, and which is ordinarily shunted by a fixed condenser, thence to the positive side of a high-voltage battery marked B^2, the negative side of which goes to the common filament terminal. The filament is fed by a battery B^1. The battery B^1 and the battery B^2 and the receiver R are usually external to the receiver. In operating this set the adjustment of the two coupled resonant circuits to the incoming wave length is the same as that described by me in referring to the sketch headed "Receiver arranged with terminals for any form of detector." The coupling between coils j^1 and j^2 may be varied to any degree required for selectivity and strength of signal. The filament F of the vacuum tube is brought to a suitable degree of incandescence by the battery B^1 and suitable controlling means not shown in the schematic drawing. The grid condenser h^3 is adjusted to the value required for the particular use of the valve, whether for regeneration or oscillation. To receive signals with the regenerative feature of the valve, the coupling between the tickler coil j^3 and the secondary coil j^2 is made small. In practice this coupling is brought up from its minimum value to a value where maximum regenerative amplification is obtained just below the oscillation point. If it is desired to have the vacuum tube oscillating the chief factor in determining this is an increase in the coupling between the coils j^2 and j^3.

This receiver is the one referred to in the patent board's report as "Receiver having built-in accommodations for [fol. 386] vacuum tube, arranged both for oscillation and regeneration." These receivers were purchased by and made by the Navy from about the middle of 1915 until I left the Navy in 1919.

Eight. The Navy purchased a large number of arc transmitters, both high power and low power. The first of these was obtained from the Federal Telegraph Co., and was in-

stalled at the Arlington Radio Station. I worked with this set for many months. I also worked with a great many other of the arcs, installing them as well as operating them.

The first installation—the Arlington one—was made in 1914, and others followed soon thereafter. I have read the testimony of Graham as to the component parts and operation of this set and I find it correct. I have examined plaintiff's Exhibit 104, Waterman diagram of Arlington Federal arc transmitter, and it is schematically correct. These transmitters all were characterized by large loading inductances in the antenna, since they were used for long-wave lengths.

Nine. The Navy purchased many thousands of vacuum tubes, both for transmitting and receiving, in the period from May, 1914, to the middle of 1919. A few vacuum tubes were purchased prior to May, 1914. The receiving vacuum tubes were used as detectors, as amplifiers, and as oscillators. The transmitting vacuum tubes were used as oscillator, modulator, and amplifier. The chief value of these tubes lay in their amplifier characteristics, as there is no other practical way known for obtaining amplification. Their use enabled long-distance communication to become an assured fact. A second very valuable feature was the ability to oscillate, particularly in receiving, as the oscillating vacuum tube was the only practical way for receiving continuous wave-telegraph signals.

I have read the testimony of Mr. Graham relative to the audion and find it to be correct. The schematic drawing of plaintiff's Exhibit 83 correctly represents schematically the three elements essential to an audion (or vacuum tube or valve by which name it is frequently known), as well as the necessary auxiliary devices.

The Navy Department had large quantities of these vacuum tubes in store when I left in 1919, and subsequently sold a number of these to commercial concerns. I have seen these tubes in stores of various dealers and know of the circumstances surrounding the sale.

Ten. Direction finder: The Navy bought and installed a large number of direction finder outfits before and during the war. The first installation was 1915 or 1916. Practically every vessel had a direction finder on board and a large number of shore direction finders stations were erected. I was frequently detailed to watch the experimental development of these devices at the Philadelphia

Navy Yard and their installation at various locations on shore and ship.

The direction finder consists essentially of a rotatable coil of wire which is used in place of an ordinary vertical antenna to pick up radio signals, the strength of these signals varying from a maximum to a minimum, depending on the angle made by the plane of the coil with the axis of incoming signals. This loop aerial, as the rotating coil is called, is connected to an ordinary receiver, which has a special feature in that the primary circuit is in two parts, one connecting the loop aerial referred to and the other to a vertical antenna. Both these primaries are coupled to a [fol. 387] single secondary resonant circuit. In operation, the loop antenna system is tuned to resonance with the incoming signal, and so is the circuit including the vertical antenna. The secondary circuit is tuned to be in resonance with the incoming signal, and hence with both of the primary circuits coupled to it. Most of the receivers supplied for this work have vacuum tubes built into them, and were arranged for regeneration and oscillation.

I have prepared a drawing, which I have here, marked "Direction finder." This drawing was made from my original sketch and I have checked it as being correct. The secondary resonant circuit consists of two coils, j^2 and j^4, usually arranged so as not to be in inductive relation with each other. These two inductances together with the variable condenser h^2, form the secondary resonant circuit which in use is tuned to the incoming signal. The arrangement of a vacuum tube, and the coupling of the feed-back coil (or tickler coil, as it is sometimes called), with the secondary inductance system, is the same as has been described by me in connection with the drawing headed "Vacuum-tube receiver arranged for both oscillations and regeneration." The loop antenna, shown as LA, connects to a primary coil j^5, which has an adjustable arm 3A, and in series with these two inductances, namely, the loop aerial and its primary, is a variable condenser h^3. The condenser h^3 and the coil j^5 are a part of the receiver. The coupling between j^5 and j^2 is variable. The vertical antenna F with its lead in A, passes through a series variable condenser h^1 and thence to a primary coil j^1, with its associated variable contact arm 3, and thence to ground E. The coupling between primary coil j^1 and the coil j^4 of the secondary inductance system is variable. The cir-

cuit F-A-h^1-j^1-3-E is tuned to the incoming signals, as is the secondary circuit, and the two form a coupled system in which both elements are in resonance with each other and with the incoming wave lengths.

Most of the receivers used with the direction finder were of this special type, but a few were used with a loop aerial only and without the vertical antenna. All these receivers for use with the direction finder have vacuum tubes or were arranged for use with vacuum tubes.

Eleven. The Navy purchased or manufactured a great number of audion detector and control boxes. The first of these were obtained in May, 1914, from DeForest and were known as type PN. I used these detectors personally. Later a modified design of audion-control box was made at the Washington yard by me, and this was the type most used in service thereafter. Plaintiff's Exhibit No. 83, drawing, PN audion, correctly represents schematically the wiring of this PN type of audion-control box. I have read the testimony of Graham as to the audion-control boxes in general, and the PN detector in particular, and I agree with him.

Twelve. A large number of vacuum-tube amplifiers were purchased and made by the Navy, beginning with about May, 1914, and continuing until I left the Navy in 1919. These amplifiers were audion amplifiers and made use of the vacuum tube.

Plaintiff's Exhibit 85, drawing, audion amplifier used by Navy, correctly shows the wiring of the first audion amplifier purchased by the Navy; this was from the DeForest company in 1914. This was a three-stage audion amplifier. The wiring diagram for a subsequent type differs in detail from that shown in Exhibit 85, par- [fol. 388] ticularly in that the secondary circuit of the interstage transformers was physically connected in some part of the circuit in later design, whereas in Exhibit 85 it is left open circuited. The operation is the same, however. In plaintiff's Exhibit 85 illustration, DeForest audion amplifier used by Navy, this is a copy of the DeForest bulletin illustrating the three-step audion amplifier, and the page stamped 192 correctly shows the device with which I worked in 1914. I have read the testimony of Graham as to the description and operation of the audion amplifier and find it correct. Plaintiff's Exhibit No. 84, official instructions for use of ultra-audion, is identified by me as

being a multigraph copy of the pamphlet gotten up by the Navy in Doctor Austin's laboratory, and copies of which were sent to all naval ships and shore stations. I was present at the Bureau of Standards when this pamphlet was being prepared and am familiar with its contents. This was sent out in the winter of 1914-1915.

Thirteen. Some receiving tuners were obtained by the Navy from time to time, the term "receiving tuner" referring to a receiver which does not have any detector apparatus associated with it. The receivers which I have previously referred to as "receivers arranged with terminals for any form of detector," fall under the class of receiving tuner as long as no crystal detector is mounted on the panel. Receiving tuners also comprise those receivers which were originally designed for one type of detector only, although in practice any such receiver can actually be used with other forms of detector. An example of this is shown in plaintiff's Exhibit No. 84, where instructions are given for using the I-P-76 receiver (originally designed for crystal detector work only), with an oscillating vacuum tube.

Receiving tuners were purchased by the Navy in the earlier days, and I think that very few were called for after about 1915.

Fourteen. Under the heading "Transmitters," strictly speaking one should consider radiotelephone sets, but since they are separately classed in the patent board's report they will be referred to separately there. The Navy bought a great many vacuum-tube type of wireless-telephone sets from 1916-1917 on to the middle of 1919, when I left the Navy. These were, in general, for use with sub-chasers, submarines, airplanes, and a few for battleship and shore-station work.

The complete report of all the radiotelephone sets purchased by the Navy is found in two publications, both of which were compiled by T. Johnson, jr., formerly radio aid, Navy Department, Washington, D. C. Early in 1919 the Navy wished to have a complete record of its activities in wireless telephone lines, and Mr. Johnson was detailed by the head of the radio division Bureau of Engineering, Navy Department, to compile such a report. This report was for the purpose of publication in the Proceedings of the Institute of Radio Engineers, in order to put before

the public the record of the Navy in this line. Similar reports were prepared by the Signal Corps. In my capacity as technical adviser to the head of the radio division, I passed on both these papers of Mr. Johnson and assisted in preparing them. I am familiar with all the apparatus described therein. The first paper was presented before the Institute of Radio Engineers by Mr. Johnson on June 4, 1919, and a reprint was issued by the Navy Department by the Government Printing Office, Washington, 1920, under the heading "Naval aircraft radio." The second [fol. 389] paper was presented by Mr. Johnson before the Institute of Radio Engineers on January 5, 1921, and was headed "Naval radio tube transmitters." I shall refer to both of these in describing the various transmitters and for brevity will refer to the Navy Department reprint, by the letters "SE," for Steam Engineering, and the Institute of Radio Engineers' booklet which contains the lecture of January 5, 1921, by the letters "IRE," standing for Institute of Radio Engineers.

From these sources I have prepared a list of the various types of tube transmitters which the Navy purchased. Photographs of these and wiring diagram thereof are to be found in either of the two books SE or IRE. The extremely simplified schematic drawings, showing only the essential elements used to create oscillations in the antenna, have been prepared by me and are four in number. These were prepared on two sheets from pencil sketches of mine, and I have checked them as being correct.

The schematic diagrams fall broadly into four classes, which are designated in these drawings as DeForest, General Electric No. 1, General Electric No. 2, and Western Electric, respectively abbreviated in further reference as DF, GE No. 1, GE No. 2, and WE.

In each of the four schematic drawings *f* represents the antenna, A the antenna down lead, *g* the antenna inductance coil, 1 the variable contact arm where such arm is present, and E the earth connection. In each of the four sketches T represents a vacuum tube, with its element, the plate, P, the grid, G, and the filament, F. B^1 represents the source of supply for rendering incandescent the filament. The supply source may be direct or alternating. B^2 represents the supply source for the plate voltage and this may be a generator or a battery. L represents a grid leak resistance where such is used.

In diagram WE, c^1 represents a series antenna condenser, which is variable, and in diagram DF, c^1 represents a series antenna condenser, which is fixed.

Referring now to each individual drawing, in diagram DF, the coil d^2 is a grid coupling coil and is inductively related with the antenna coil g. Coil d^2 is paralleled by a variable condenser cc^3. c^2 is a series grid condenser shunted by a grid leak L. The grid and plate circuit are completed to earth through the small capacity formed by the capacity of the various elements of the apparatus to ground, no direct earth connection being supplied.

In diagram GE No. 1, d^2 is a plate coupling coil, variable, by variable arm 2. d^3 is a grid coupling coil, variable by arm 3. c^1 is the series grid condenser shunted by the grid leak L. The plate and grid coupling coil d^2 and d^3, are in inductive relation with each other and with the antenna coil g.

In diagram GE No. 2, a second coil d^1, varied by the arm 2, is in series with the antenna coil g, the two together forming the total antenna inductance system. Coil d^2, variable by arm 3 is in series with a condenser c^2 and these two elements connect the plate to the filament circuit. c^1 is a series grid condenser.

In the diagram WE, condenser c^4 is the grid condenser, shunted by the leak L. Condensers c^2 and c^3 serve to couple the valve elements in such a way as to give regeneration.

The following is a list, with very approximate figures as to the number of purchase of the chief wireless-telephone [fol. 390] outfits purchased by the Navy between 1916 and the middle of 1919. The first column is the name of the manufacturer, this column being headed "Company." The second column, headed "Type of set," gives the Navy type number or model number which identifies the apparatus. The third column, headed "Photo," refers to the figure in either the Navy publication headed "Naval aircraft radio," before designated by the letters SE, or in the publication of the Institute of Radio Engineers, previously referred to and designated by the letters IRE. The fourth column, headed "Wiring diagram," similarly refers to the figure in the book SE or IRE, where the actual wiring diagram of the set can be found. The fifth column, headed "Schem. Diag.," or schematic diagram, refers to the very simplified

schematic drawing, which represents the oscillation system, which applies to each set, as shown by the appropriate one of the four schematic drawings previously referred to by me as DF, GE No. 1, GE No. 2, or WE. The sixth column, headed "Approx. No.," tells to the best of my recollection the number of sets which the Navy purchased. The last column tells what the general use of the set was—that is, the location for which the sets were purchased.

The sets were supplied by four manufacturers, DeForest, General Radio, Western Electric, and General Electric. The list giving the detail types of apparatus here follows:

Tube transmitters purchased by the United States Government

Company	Type of set	Photo	Wiring	Diag.	Schem. diag.	Approx. No.	Used in—
DeForest	Dirigible	None	Sim. to BK. SE	Fig. 10	DF	10	Dirigibles.
Genl. Radio	CAG No. 1295	Fig. 67, BK. SE	Sim. to	Fig. 66, BK. SE	GE No. 1	100	Airplane.
Western Elec.	CW No. 1058 Similar to Army type SCR68				WE	100	Airplane.
Western Elec.	CW936	Fig. 10A, BK. IRE			WE	700	Sub. chasers.
Western Elec.	Model TB					20	Battleships.
Genl. Elec	SE1380	Fig. 72, BK. SE	Fig. 74, BK. SE	GE No. 1	GE No. 1	10	Flying boats.
Genl. Elec	SE1340	Fig. 62, BK. SE	Fig. 63, BK. SE	GE	GE No. 1	200	Flying boats.
Genl. Elec	SE1370	Fig. 68, BK. SE	Fig. 70, BK. SE		GE No. 31	200	Flying boats.
Genl. Elec	SE1345	Fig. 57, BK. SE	Fig. 59, BK. SE		GE No. 1	100	Airplane.
Genl. Elec	SE1390	Fig. 80, BK. SE	Fig. 81, BK. SE		GE No. 1	20	Flying boats.
Genl. Elec	Model TC	Fig. 14, BK. IRE.	Fig. 16, BK. IRE.		GE No. 1	20	Battleship.
Genl. Elec	Model TD	Fig. 33, BK. IRE.	Fig. 32, BK. IRE.		GE No. 1	55	Base station.
Genl. Elec	Model TE	Fig. 25, BK. IRE.	Fig. 26, BK, IRE.		GE No. 2	60	Submarine.

Some of these sets were supplied as transmitters only, without receivers. Some were supplied with external receivers, and a few, particularly the Western Electric CW936, sub-chaser set, have the receiver built in. When the receivers were built in to the set they corresponded to the class designated by the patent board report as receivers having built-in accommodations for vacuum tubes and arranged both for oscillations and regeneration. The West- [fol. 391] ern Electric receiver circuit is shown on the left-hand side of Figure 9, book IRE, and this shows two resonant tuned circuits coupled. A vacuum tube detector and two stages of audio amplification were included. These receivers were designed so that they could receive any kind of signal, from another continuous-wave telephone set or from a spark set. I have used these many times myself for receiving from all classes of Navy vessels, whether fitted with tube transmitters or the standard inductively coupled spark transmitter.

In cases where receivers were purchased with the transmitters, these receivers being separate articles, the chief reason why we purchased the receivers at the same time as the transmitters was because it made it easier to obtain both these articles in one requisition. In other cases we took receivers from stock and added them to transmitters which we bought separately. In practically every case the receivers used were the standard Navy two-circuit receiver, with two tuned circuits, and in the majority of cases with vacuum tubes built in and with provision for regeneration and oscillation. A few airplane sets were purchased where the receivers did not have a primary and a secondary circuit, each resonant to the incoming wave lengths, as such, but have the vacuum tube connected directly to the antenna inductance. These receivers were fitted with tickler coil in the plate circuit, inductively coupled with the antenna.

Fifteen. Referring to wave changers, another subclass in the patent board report, these devices essentially consisted of switching means attached to already existing loading and coupling inductances in transmitter circuit, or containing built-in loading and coupling inductances which replaced others formerly present in the set.

Sixteen. Referring to the item "Variometers," which appears in the patent board report, a number of the Telefunken transmitting sets which were purchased around 1912 or shortly thereafter, contained variometers in their cir-

cuits. Variometers were also used in receiving sets built by the Navy in or about 1918, and I think that some of these were purchased with these features in them. A variometer is in general merely a variable inductance forming a part or all of the tuning inductance in the circuit, and being variable by a particular way—that is, by variation of the mutual inductance between two of its parts.

3. Question. Please describe briefly the sets which you refer to as "spark sets for vacuum excitations."

Answer. These sets are of the type referred to in the patent board report as "Transmitters with (four) vacuum tubes excitation." These sets were originally coupled spark transmitters, which were modified so as to be capable of excitation by vacuum tubes. Part of the spark apparatus was retained, for example, the motor generator and transformers, and other apparatus was added, such as vacuum tubes, rectifying tubes, and various parts of the coupling circuits. The set when completed became practically equivalent to a continuous-wave radio telegraph transmitter, and any one of the circuits shown schematically in my drawings DF, GE No. 1, GE No. 2, or WE, could have been used.

[fol. 392] 4. Question. You stated that the vacuum tubes purchased were used either as detectors, amplifiers, oscillators, modulators. Can you refer to the circuits in which they were used?

Answer. In receiving work a typical circuit showing the use of the valve or audion as a detector is found in plaintiff's Exhibit 83; its use as an amplifier and the circuit in which it would be so used is correctly shown in plaintiff's Exhibit 85. Its use as an oscillator is shown as to one type in plaintiff's Exhibit 109, as well as in the drawing which I have produced headed "Vacuum-tube receiver arranged for both oscillations and regenerations."

The use of the vacuum tube as a transmitting oscillator is exemplified most clearly in my schematic drawing GE No. 1 and another more complete wiring diagram showing this is found in Figure 32 of the book IRE, where the three vacuum tubes on the left are always used as oscillators to generate oscillations. The use of a transmitting vacuum tube as a modulator to modify the output of some other oscillator tube is shown in this same Figure 32, where the fourth, fifth, and sixth tubes in the diagram, reading from left to right, were used as modulators when the set was operated as a wireless telephone set. The use of the trans-

mitting vacuum tube as an amplifier is again shown in Figure 32, where the extreme right hand tube is a 5-watt transmitting tube used to amplify the speech output of the microphone before impressing it upon the modulator tube.

5. Question. During the years 1912 to 1915, inclusive, to what extent were loading coils, such for example as those shown at G and G′ in Exhibit No. 87, employed in the radio receivers and transmitters used by the Navy and what advantages, if any, were derived from their use?

Answer. Loading coils such as transmitter load coils G and receiver load coil G′ formed a part of practically every transmitter and receiver bought by the Navy during the years 1912 to 1915. These coils were an integral part of both transmitter and receiver, rendering it possible to operate these pieces of apparatus over a wider range of wave length and particularly to enable long wave lengths to be reached.

6. Question. To what extent were transmitters and receivers, each having coupled tuned circuits of the kind shown, for example, in plaintiff's Exhibit No. 87, employed by the Navy Department during the period beginning March, 1912, and ending in 1919?

Answer. By far the greater number of spark transmitters purchased by the Navy during the above period were transmitters embodying coupled tuned circuits. All the quenched gap sets which formed the bulk of spark transmitters in the Navy were of this type. The receivers were almost exclusively of this type, mainly, having two coupled circuits, each tunable to the desired wave length. With the exception of the airplane receivers referred to in a previous answer, which did not per se contain the tuned secondary circuit with variable condenser, I do not recall that receivers of any other type were in use or purchased during that period.

7. Question. What improvement, if any, in the Navy radio service resulted from the introduction and use of vacuum tube receivers and transmitters of the several kinds you have testified about?

Answer. They were both an indispensable part of naval radio. In receiving the vacuum tube amplifier made long-[fol. 393] distance work possible for the first time, and the use of the tube as an oscillator in the receiving circuit is the only practical way to receive continuous-waves telegraph signals. This is especially positively stated when

I recall the difficulties experienced in trying to receive the early arc stations before the oscillating audions became available. In transmitting, the vacuum tube, for one thing, made naval air craft radio possible, particularly as to radio telephony, and the use of the vacuum-tube transmitter in other locations provides the simplest and most practical form of excitation for continuous-wave work. In telephony its necessity is essential. Without it radio telephony would not be to-day possible for the everyday ship and shore stations.

By Mr. Peters: I offer in evidence the following drawings used and referred to by the witness in his testimony:

Drawing marked "Typical transmitter with rotating gap," plaintiff's Exhibit No. 112.

Drawing marked "Receiver arranged with terminals for any form of detector," plaintiff's Exhibit No. 113.

Drawing marked "Vacuum-tube receiver arranged for both oscillations and regeneration," plaintiff's Exhibit No. 114.

Drawing marked "Direction finder," plaintiff's Exhibit No. 115.

Drawing comprising two sheets, marked "Vacuum-tube transmitters for radiotelephony," plaintiff's Exhibit No. 116.

Publication entitled "Naval Aircraft Radio," issued by Navy Department, Bureau of Steam Engineering, Washington, D. C., June, 1919, plaintiff's Exhibit No. 117.

Also article in proceedings of Radio Institute of Engineers, October, 1921, by T. Johnson, jr., comprised between pages 381 and 433, entitled "Naval radio tube transmitters," plaintiff's Exhibit No. 118.

*   *   *   *   *   *   *

8. Question. During the time the United States was engaged in the World War did the Navy Department assume any, and if what, responsibility as to infringement of radio apparatus purchased by it? State your own knowledge and refer to any Government document known to you.

*   *   *   *   *   *   *

Answer. In my position as adviser to the head of the radio division the matter of the liability of companies for damages due to patent infringement was often discussed.

Prior to the war all companies had signed a contract in which they guaranteed to save the Government harmless in case of prosecution on infringement of patents. When the Western Electric Co. was given the first big order for war material it brought the point that it could not proceed with the contract unless the Government would agree to withdraw this requirement. It was recognized that in times of emergency the only thing that counted was getting the material out, so the Navy Department agreed to remove the clause and allow the Western Electric Co. to supply the apparatus without any question of guarantee against pat-[fol. 394] ent suits. This was done also for other companies of which I personally know.

On pages 20 to 21 of the patent board report appears a detailed statement with reference to this fact. This statement is contained in the last two lines of page 20 and the first 44 lines of page 21.

The statement is as follows:

"In January and February, 1918, the Western Electric Co. prior to final decision by the Supreme Court in the Cramp and Simon cases, below mentioned, had insisted, as to its contracts with the Government, that it (Western Electric Co.) be held harmless in any patent litigation. In one such contract, for example, relating to a radio apparatus designated as an audio frequency amplifier the supply officer at the navy yard in New York was instructed to award the contract to the Western Electric Co. subject to the following condition:

" 'The apparatus mentioned herein being required without delay by the United States Government, said apparatus is furnished in this emergency without investigation of outstanding patents, upon the condition (to which the United States in placing its order agrees) that the United States will save the Western Electric Co. (Inc.) harmless from all claims for infringement of patents on account of the apparatus so furnished, the Government assuming with the patentees direct all responsibility for said patent infringement.'

"On March 4, 1918, the United States Supreme Court, in the cases of William Cramp & Sons Ship & Engine Building Co. *v.* International Curtis Marine Turbine Co. (246 U. S. 28) and Marconi Wireless Telegraph Co. *v.* Simon,

(246 U. S. 46), having rendered the opinion that in certain cases contractors with the Government were not protected by the act of 1910 from independent liability, it was represented to the Government, and particularly to the War and Navy Departments, that contractors could no longer safely undertake the warranty against infringement. See in this connection the letter from DeForest Co., dated March 14, 1918. Similar letters were received from the National Electrical Supply Co., the Wireless Improvement Co., Emil J. Simon, the Wireless Specialty Apparatus Co., Kilbourne & Clark Manufacturing Co., and the Sperry Gyroscope Co.

"The contracts with the Western Electric Co. referred to in said letter had been made prior to the rendering of the decisions in the Cramp and Simon cases, the Western Electric Co. having (as already stated) made their bids in certain cases only on condition that such warranty be given. At this time there had been called to the attention of the Government claims of various companies owning patents for radio apparatus, particular stress being laid upon claims arising under adjudicated patents of the Marconi Wireless Telegraph Co. of America, the International Radio Telegraph Co., and the DeForest Radio Telephone & Telegraph Co.

"On March 29, 1918, the Acting Secretary of the Navy caused to be addressed to the DeForest Radio Telephone & Telegraph Co. a communication accepting certain responsibility on the part of the Government for the protection of contractors against patent claims, and, by direction of the Secretary, the Bureau of Supplies and Accounts, Navy Department, was, on April 3, 1918, notified that letters of similar purport to that sent to the DeForest Co. [fol. 395] would be sent by the department from time to time to other contractors where it appeared that such action was necessary, in addition to those mentioned in the first indorsement of the Solicitor for the Navy Department on April 3, 1918.

"The Secretary of War issued similar orders, and the Secretary of the Navy did likewise in several additional instances."

* * * * * * *

9. Question. The report of the patent board to which you refer is published where?

* * * * * * *

Answer. The quotation given is from a publication entitled "Hearings before the Committee on Military Affairs, House of Representatives, Sixty-seventh Congress, first session, Monday, May 23, 1921," the subject being further given as "Radio patents, settlement of claims against Government for use of radio patents during the World War." The publication is marked with the data "Washington, Government Printing Office, 1921."

(Direct examination closed.)

The said witness was then cross-examined by the counsel for the defendant, and, in answer to interrogatories, testified as follows:

10. Cross-question. You testified as a witness for the plaintiff in the case of Marconi Wireless Telegraph Co. of America against the DeForest Radio Telephone & Telegraph Co. and Lee DeForest in the United States District Court for the Southern District of New York, did you not?

Answer. Yes.

11. Cross-question. The "audion apparatus" to which you there refer in your testimony was the same three-element vacuum bulb concerning which you have testified in this case, was it not?

Answer. Yes; the same audion.

12. Cross-question. Testifying with reference to that apparatus, did you not there testify as follows:

"Q. Please compare the value and utility of this audion apparatus involved in these accounts with other types of apparatus available for use for the same general purposes at the time the audion apparatus was purchased.

"A. The apparatus referred to in the list which I saw consists in general of the two general classes of the audion as a detector or oscillator and the audion as an amplifier, using the term 'audion' to include the particular control system and bulb, which is the apparatus which we purchased. Taking the first part, the oscillating audion, prior to the purchase by the Navy of the DeForest apparatus there were three general types of apparatus which were used for this purpose—first, the ticker; second, the tone wheel; third, the arc form of heterodyne of the National Electric Signaling Co. These were all devices which would enable signals to be detected from continuous-wave transmitters such as the arc or alternator. Considering these

one by one, the ticker was the only device which was at all useful, and it was far below the standard of the DeForest [fol. 396] oscillating audion or ultraaudion, as it was termed at that time. The chief faults of the ticker were, first, its lack of sensitiveness, and, second, the grave fault, that it was difficult to distinguish signals and atmospheric disturbances, in that both had very much the same sound. When the DeForest apparatus was used it was possible to distinguish between the atmospheric disturbances and the signal very much more efficiently, first, on account of the increased sensitiveness of the DeForest apparatus, which enabled the full advantages of loose coupling in the receiver to be made use of, and, second, because with the DeForest apparatus it was possible to obtain a clear musical note from the signal, whereas the static note remained rather unmusical and very much different in quality.

"The tone wheel was never purchased by the Navy Department, and I recall only one case where it was even seen by any member of the naval forces. That was at the high-power station at Tuckerton, where one of these instruments was available. I tested this apparatus for a long time and found it absolutely unreliable and not satisfactory for a radio-receiving device.

"The third apparatus, the arc form of heterodyne, was purchased by the Navy to a very small extent, in that three sets of this apparatus were obtained as an adjunct or part of a high-power transmitting system which was purchased by the Navy. The arc heterodyne was tested by me on the voyage of the U. S. S. *Salem* to Gibraltar and back, and my notes of the voyage and my present memory show that it was — very reliable. The arc was constantly getting out of adjustment, and the apparatus required a very skilled operator to keep it in shape, but the chief disadvantage was that noises from the arc, such as hissing and sputtering, were constantly present and interfered very greatly with the intended function of the apparatus. No further sets of this type were obtained by the Navy, and the use of the heterodyne method of receiving was not taken advantage of until the demonstration by Dr. DeForest of his apparatus.

"Referring now to the second general classification, the amplifier, prior to the DeForest amplifier the only types of apparatus known to the Navy for this apparatus were of the carbon microphone class, and all of these devices in-

troduced so much noise, due to frying of the carbon and other causes, as to defeat entirely the aim of the apparatus, where, as the signals were amplified, so many additional noises were brought in that the actual readability of the signal was lessened. Some of these instruments were purchased, but none were ever put into actual use for this reason. In March, 1914, I witnessed a demonstration by Dr. DeForest of his oscillating audion at the Bureau of Standards in Washington, and I considered that this was a wonderful piece of apparatus. I recommended to the Navy that we purchase a number of these instruments. A requisition was very quickly made for a number of pieces of apparatus, and they were delivered and used in a very short time. From that time on we have continued the use of this general form of device without exception. I consider that the oscillating audion marked a distinct step in the art of radio communication. I considered at the time that I first saw it that it was a very wonderful advance, and I have never changed my point of view. Just at that time the Navy was introducing high-power arc transmitters in the endeavor to obtain long-range communication. That [fol. 397] long-range communication would not have been possible with any of the known detectors at the time, nor would it have been possible without amplification, and therefore I consider that the use of the DeForest wireless device, the oscillating audion, and the amplifier are absolutely indispensable in maintaining long-distance communication in the Navy, which has been of the greatest military value. I think I can put the thing more clearly and simply by saying that my general idea is that the oscillating audion and the amplifier are of inestimable value in the art of radio communication."

Answer. Yes; I recall that testimony.

13. Cross-question. In the same case did you also give the following testimony?

"Q. The electrolytic detector—does that amplify?—A. It is a detector pure and simple, and in the sense that I stated before it falls in the same category as the crystal detector. I have never seen it used other than as the original detector of signals.

"Q. But if you had to depend upon the electrolytic device and added a battery to that, then the limit of amplification would be about the same as that of the crystal detector?—A. I don't accept the use of the word 'ampli-

fication' at all there. Neither of these devices was in any sense an amplifier. They were merely detectors.

"Q. That is, even if you here added a battery circuit to the crystal detector or the electrolytic detector that would not be what you understand to be an amplifier?—A. That would be what I understand as an increase in the sensitiveness of the detector. That in a sense is an amplification, but we have never called it such.

"Q. In order to straighten this out will you try to give us a little clearer idea of the distinction that you draw between increase of sensitiveness by adding a battery and what you call amplification or real amplification?—A. The general understanding that the Navy has as reflected in its purchases and its general policies with which I am acquainted is as follows: A device for indicating the presence of radio frequency energy is a detector. The sensitiveness of that detector is a variable quantity, depending on a number of factors. In the case of the crystal detector is depends on finding sensitive points of the crystal; it depends on the presence or absence of the battery and the correct adjustment of said battery. In the case of the electrolytic it depends on the diameter of the wire, the immersion of the wire in the liquid, the presence of a battery, and the correct adjustment of that battery. Now, having obtained a signal from said primary detector we may make use of other apparatus which is entirely separate in form for increasing its energy. Of these amplifiers the carbon microphone, which I mentioned, is one. The DeForest audion amplifier is another. But I have always used and the Navy has always used the term amplifier to mean a piece of apparatus used as the second step in the reception of a radio signal."

Answer. Yes; I recall that testimony.

14. Cross-question. In the same case did you also give the following testimony?

"Q. Did you ever try or use any of the incandescent lamp bulbs in which there was only a plate and a filament?—A. Yes; I have.

"Q. To what extent?—A. In one set of apparatus only, furnished by the Marconi company, and which I used to a very limited extent, and only as incidental to certain experiments with direction finders."

[fol. 398] Answer. Yes; I recall that testimony.

15. Cross-question. In the same case did you also give the following testimony?

"Would you say that it would amplify to any greater extent than the crystal detector or the electrolytic detector?—A. Not having made the exact test, I don't wish to give testimony.

"Q. But you did express the opinion that these results would be impossible without the DeForest device over and above anything that was known at that time?—A. This device which I used from the Marconi company was not an amplifier in the naval sense of the term. It was a detector, and a detector of damped signals pure and simple. As such we did not even think of it as being a possible amplifier; and I am referring, as I said, to apparatus which we used. It was submitted as a detector, to be used as an alternative to the crystal detector in the same set."

Answer. Yes; I recall that testimony.

16. Cross-question. In the same case did you also give the following testimony?

"Q. Were any of these amplifying devices used by being connected to a crystal detector?—A. Yes. Probably as many as were used with an audion as the original detector. Probably more. Possibly more.

"Q. In that case the impulses would be detected by the crystal detector, and the audio frequency from the crystal detector would be amplified in the audion bulb or bulbs?—A. That is the commonly accepted idea."

Answer. Yes; I recall that testimony.

17. Cross-question. In the same case, did you also give the following testimony?

"Q. Generally it is true, is it not, that the potential on the grid ought to be very much below that on the plate?—A. Yes; that should be.

"Q. And that if the grid voltage should be the same as the plate voltage, then you would not get the amplification?—A. That is true.

"Q. That is, if the grid were connected to the plate, either on a wire or so that you would have the same voltage, then you would not get the amplification or the oscillation of the device? Am I right?—A. I never tried

that experiment. Again, that is in the realm of theory. I don't know.

"Q. But you do know that in practice the potential on the grid is very much below that of the plate, do you not?—A. As the apparatus was supplied us; yes. Whether or not you could make it work by redesigning it for that particular use, I don't know, not having tried it.

"Q. So far as you know, it was always used with the lower grid potential, was it not?—A. I am speaking now just from elementary theory; yes; but there was no specific means provided from which you could specifically say that this was lower voltage. For instance, in any of the apparatus we got from the DeForest Co. there was no additional battery supplied for deliberately changing the voltage of the grid electrode.

"Q. But there was a connection from the grid to the filament in the bulb, was there not; in the device itself? [fol. 399] It contained a connection from the filament to the grid?—A. Not a direct wire connection; no; but there was a connection—yes—an electrical circuit.

"Q. That would be the receiving circuit?—A. Yes.

"Q. And the result of that would be that the potential of the grid would be approximately that of the filament normally, would it not?—A. Other than for the presence of the stopping condenser or grid condenser, which was present in all the sets.

"Q. And how would that affect it?—A. That I don't wish to answer. It would mean that there would not be direct current potential from the plate battery impressed on the grid, and therefore it puts the actual determination of the voltage into the realm of the theoretical, on which I do not wish to estimate.

"Q. That would mean, in effect, would it not, that the voltage on the grid would depend entirely on the current in the receiving circuit rather than in the battery *current in the receiving circuit rather than in the battery* circuit, would it not?—A. Would depend entirely; yes.

"Q. Of course, as I understand you, if that grid were connected to the plate, then that would not necessarily be true, would it?—A. I would not necessarily say so without having done it."

Answer. Yes; I recall that testimony.

18. Cross-question. In the same case, did you also give the following testimony?

"Q. Were any of these amplifying devices used by being connected to a crystal detector?—A. Yes. Probably as many as were used with an audion as the original detector. Probably more. Possibly more.

"Q. In that case the impulses would be detected by the crystal detector, and the audio frequency from the crystal detector would be amplified in the audion bulb or bulbs?—A. That is the commonly accepted idea."

Answer. Yes; I recall that testimony.

19. Cross-question. All of the vacuum tubes purchased by the Navy, from May, 1914, to the middle of 1919, for the period covered by your testimony, and concerning which you have testified, were of the three-electrode type, were they not?

Answer. Yes.

20. Cross-question. And the bulbs referred to under subdivisions nine, ten, eleven, twelve, thirteen, and fourteen of your answer to Q. 2, referred to these same three-electrode vacuum tubes. Is that correct?

Answer. There were probably some two-electrode tubes purchased prior to the middle of 1919, known as kenetrons, but my testimony was entirely concerned with the three-electrode tubes used in the purely radio part of the circuit. The kenetrons, if supplied prior to that date, were used for rectification of the A. C. power supply.

21. Cross-question. Were all of the tubes concerning which you have testified of the hard vacuum type?

Answer. By far the greater majority were. A few of the earlier ones were not.

22. Cross-question. Generally speaking, the ones which were not were those made by the DeForest company, were they not?

Answer. Yes.

23. Cross-question. And generally speaking, the other types were of the hard vacuum type, were they not?

[fol. 400] Answer. Relatively hard, compared with the strictly soft tubes. I do not recall whether the degree of exhaustion in all of the tubes was carried to the ultimate degree possible or not, but they would all be known in the trade as hard rather than soft tubes.

24. Cross-question. What is the difference in performance characteristics between the hard vacuum tube and the soft tubes, such, for example, as the DeForest tubes?

Answer. Testifying entirely as to the period covered by my Navy experience, the chief difference known at that time was that the hard tubes were more uniform in operating functions, whereas the soft tubes varied greatly in sensitiveness. Some of the soft tubes would be very much more sensitive as detectors than the standards for the hard tubes, and others would be very much less sensitive, as used in the period referred to. Another characteristic noted was much greater plate voltage could be used with the hard tube. With the soft tube there was very great possibility of causing what is known as a blue glow in the tubes if the voltage were above a certain value.

25. Cross-question. Can you say what caused the uncertain performance of the soft vacuum tubes?

Answer. That is a matter of theory and not of practical engineering, and I wish to testify as to what I actually know through performance rather than theory.

26. Cross-question. Referring to the amplifiers referred to by you under subdivision twelve, were these adapted to amplify currents of radio frequency or currents of audio frequency?

Answer. They were purchased and used as audio amplifiers.

27. Cross-question. Referring to the plaintiff's Exhibit No. 85, this could be used by connecting the terminals XY to an ordinary telephone circuit, could it not?

Answer. Yes.

28. Cross-question. Was it such a device as this, for example, as was used in transmitting telephone signals from the flying boat to the office of the Secretary of the Navy described on pages 101 and 102 of the plaintiff's Exhibit No. 117?

Answer. By "transmitting telephone signals from the flying boat" I presume that you mean relaying the received signals received at the navy yard, Washington, from the flying boat and thence relayed to the Secretary's office. I did not witness this test and can not specifically answer your question. In general, the circuit referred to is the type of audio amplifier, with minor modifications, that was used in the service up to the time I left. The publication from which you quote, which is the official report of this test, states that two stages of audio frequency were used, and therefore the circuits used in the test were of the same

general nature as those shown in Exhibit No. 85, with minor modifications as the art progressed.

29. Cross-question. Where the amplifier was used in work similar to the example given in the publication referred to, I take it the signals were transmitted from the transmitting station at radio frequency to a receiving station—for example, the Washington Navy Yard—and there in some manner changed to audio frequency, and these audio frequencies were amplified in the amplifier device of which Exhibit No. 85 is the diagram, and the amplified audio frequencies transmitted over a telephone wire. Am I right in understanding that was one of the uses of these amplifiers?

[fol. 401] Answer. Yes.

30. Cross-question. So far as the change from radio frequency to audio frequency was concerned, this might be accomplished by a vacuum tube or a crystal detector or any other suitable device, could it not?

Answer. Yes.

31. Cross-question. Were crystal detectors used for this purpose by the Navy?

Answer. When the first vacuum tube purchases were made in 1914 and tried out in service a conference was held at Washington, in which it was definitely decided to equip all ships and stations in time with the vacuum-tube detector and with amplifiers of this type. On account of the fact that not enough money was available to do this at once, it was decided to begin with the more important stations and ships, fitting these with vacuum-tube detectors and with amplifiers. Stations and ships of next importance were supplied with amplifiers only to be used with the crystal detectors which they had. Stations of still lesser importance were for the time left as they were. Instructions were given that the stations having complete vacuum-tube outfits would use them for long-distance work only and use the crystal for short-distance work to save replacement cost. As fast as money became available every station under the Navy Department obtained vacuum-tube detectors and amplifiers. The policy was clearly determined long in advance of the money being available.

32. Cross-question. When you say stations of lesser importance were left as they were does that mean that they were left with the crystal detectors for detecting purposes?

Answer. Yes.

33. Cross-question. Were they supplied with amplifiers to use in connection with these crystal detectors?

Answer. As stated in my previous answer, not at first. The line of progress was very clearly marked, in that the lesser stations were first left alone with the crystal detectors they had, then later obtained amplifiers as the money became available, and still later obtained regenerative receivers with the vacuum-tube detector in use.

34. Cross-question. You say the stations with crystal detectors were not at first supplied with the amplifiers. Were they supplied with amplifiers later?

Answer. Yes, sir; I have so testified.

35. Cross-question. Then the process of transformation, as I understand, would be substantially as follows: A station with a crystal detector would be supplied with an amplifier, then later a tube would be supplied to take the place of the detector. Am I right in that understanding?

Answer. In order to make this clear, I will repeat my previous testimony. You are correct, as I stated before, only in the case of stations whose importance was such that they did not warrant getting the first supply of vacuum tube equipment which could be purchased with the limited funds available when the vacuum tube detector and amplifier became available. A number of stations, shore as well as ship, were immediately equipped with vacuum tube detector and amplifier throughout, retaining their crystal [fol. 402] equipment for short-range work. Another group were fitted out then or shortly thereafter with the amplifier only for to equip them for taking full advantage of the vacuum tube detector would have meant replacing their nonregenerative receivers with regenerative receivers. Your supposition is correct only for the stations of least importance.

36. Cross-question. And in the stations of greater importance, the crystal detector was still retained for short-range work, was it not?

Answer. Yes.

Redirect examination.

By Mr. Peters:

Mr. Peters: I request that the pamphlet containing the hearings on the Committee on Military Affairs, referred to

the testimony by the witness during the course of his examination be marked for identification.

* * * * * * *

37. Redirect question. Did you ever have occasion to compare the sensitiveness of the two-element vacuum tube detector and the crystal detector?

Answer. Yes. I made a number of such tests in 1910 or 1911, in connection with a Bellani-Tosi direction finder, which the Navy purchased. This has two-element valves, and in testing it I compared these valves with a crystal a number of times.

38. Redirect question. What was the result of the comparison?

Answer. The two-element valve was of the same general order of sensitiveness as the crystal. By this I mean that the difference in sensitiveness was not, say, ten to one, but of a much less value. I recall that the valve was, of the two, the more sensitive. Possibly it was twice as sensitive.

39. Redirect question. Were the amplifiers purchased by the Navy Department, such as that shown in Exhibit No. 85, used in any other way than in connection with a separate detector?

Answer. Yes. The first amplifier, the DeForest, one whose circuit is shown in Exhibit No. 85, were sometimes used with the first valve, as a detector, and the second and third as amplifiers. To do this, of course, the circuit connections were not those shown in Exhibit No. 85, in that the receiver, instead of being connected to binding posts XY, were connected to the grid and filament of the first valve. I remember writing instructions for the service directing how this was to be done. The valves at that time were provided with flexible wires for the grid and plate, with different colored coverings, and I remember especially that the instructions referred to connecting the grid side of the receiving circuit to the green or grid wire of the valve and the other side of the receiving circuit to one of the common filament connections.

40. Redirect question. You have drawn a distinction between detecting and amplifying. Will you please state just what you mean by detecting and what you mean by amplifying? Define these terms as you understand them.

[fol. 403] Answer. This is a matter of nomenclature, in which I have always been very interested. While in the

naval service I, got up the first system of nomenclature, or standard names, for apparatus and their functions, which was ever prepared for this service, and after coming with the Radio Corporation I got up a much revised and more complete standard nomenclature list, which it and the General Electric Co. have adopted. I have also worked with the nomenclature committee of the Institute of Radio Engineers. The question of defining detection and amplification has always been one on which there were two points of view. Take, for example, the case of a vacuum tube, connected to a receiving set, with every precaution taken to avoid to the utmost any question of regeneration or oscillation. My definition of such a valve would be that it was a detector, in that the function which it chiefly performs, that of rectification, was the same as the function performed by the crystal detector. On closer examination, this is a narrow view to take, because it really defines the valve in terms of one particular other type of device, namely, the crystal detector, and not as to the general function which the valve is performing. It was in this narrow sense that I have referred in my Navy work and in some previous testimony to the valve as a detector.

Now, consider what happens if the valve is connected in the ultra-audion connection, or with a variable feed-back. In the latter case, as the coupling of the feed-back is increased, what you hear in the telephone, namely, the signal, is increased in strength. According to one viewpoint, it might be said that we were aiding to the rectifying feature of the valve—another quality which was similarly inherent in the valve, namely, its amplification ability. In my Navy work I looked upon the functions of the valve in this case as two simultaneous ones, namely, detection and amplification. My later view, which is in accordance with the standard definitions which the Institute of Radio Engineers has published, is that this vacuum tube and its associated local control forms a device which is interposed between the radio frequency receiver circuit and some sense of the receiving operator, such as his hearing, and that this whole device, which makes the inaudible radio signal audible, or noticeable in some other way, is called the detector system.

41. Redirect question. With what type of transmitters were the wave changers about which you have testified used?

Answer. Almost all of them were used with quenched gap-spark transmitters, such as the Wireless Specialty set,

whose se-ematic drawing is shown in the left-hand side of Plaintiff's Exhibit No. 87; also in the Lowenstein transmitters and many others.

42. Redirect question. When were these wave changers purchased by the Navy Department?

Answer. From some time in 1913 until the middle of 1919, when I left the Government service.

43. Redirect question. To what extent were the amplifying arrangements purchased by the Navy Department used in the way described in your 28th answer?

Answer. During the period from May, 1914, until the middle of 1919, I used such amplifiers in the way described, one only, for transferring received signals at the Washington yard to an official in the Navy Department.
[fol. 404] Every one of these amplifiers for the specifications of which during the entire time I was in the service were prepared by me called for a design suitable for use with a radio receiver in transferring signals from the detector thereof to an operator's telephone and amplifying them in this transfer. The use of such amplifiers in the method referred to in my answer to question 28 was occasional only, and possibly a few amplifiers out of every thousand were so used.

44. Redirect question. Please state in a general way how the radio apparatus used by the Signal Corps compared with that which you have described in detail as having been used by the Navy.

Answer. Much of the apparatus was absolutely identical. The Signal Corps obtained a great many receivers, for example, from the Navy. The apparatus which I saw in the Signal Corps from time to time was electrically exactly the same as the Navy apparatus; the engineering designs and circuits were the same. Such differences as existed were mechanical. For instance, the Signal Corps had to provide against rough transportation in the field, whereas the chief features that the Navy apparatus had to be designed to meet were salt spray and shock due to gunfire.

Recross-examination.

By Mr. Edwards:

45. Recross-question. Were the tests referred to in your answer to redirect question 37 the same ones to which refer-

ence was made in your testimony in the De Forest case, quoted in cross-question 14 of this deposition?

Answer. Yes.

46. Recross-question. Your test on this occasion was not directly for the purpose of comparing the sensitiveness of the valve and the crystal, was it?

Answer. Yes; just that.

47. Recross-question. In your testimony in the De Forest case you referred to this test as being only incidental to certain experiments with direction finders. What was the direct experiment or test made at this time?

Answer. Obviously any test consists of a large number of subsidiary or auxiliary tests any one of which is complete in itself as to its local conclusions. My main object in testing the Bellani-Tosi detector was to determine its efficiency for naval use, and this included an investigation into any possible way of improving it. One test I made was to determine whether the indication of the direction finder gave a line of bearing only or an absolute direction, and I found the former to be the case. Further tests then went on along this line until I found an improvement which would give absolute direction. A second subsidiary test was to try the efficiency of the detector supplied with the direction finder, namely, the two-element valve with the standard detector in the Navy at that time, and that test, while related to the main test, was also a separate and complete test of its own. It gave the results of the effect produced in receiving telephones on incoming wave signals, using a receiving circuit of the general type then standard, when first one and then the other detector was put in place.

48. Recross-question. Was the two-element valve furnished as a part of the Bellani-Tosi direction finder?

[fol. 405] Answer. Yes; it was.

49. Recross-question. Who furnished this device to the Navy?

Answer. I do not recall whether this was purchased in the usual way or was obtained by one of our naval attachés abroad. It was sent to Washington yard, I remember, in a way which was not according to Navy routine, and my recollection is that this may have been a special piece of apparatus that was being tried out and that may have been obtained as a loan or in some other way.

50. Recross-question. It was furnished by the Marconi company, was it not?

Answer. I am not sure now. We got some later from that company but I am not sure about this original set.

51. Recross-question. How many of these Bellani-Tosi direction finders were purchased or acquired or used by the Navy as far as you know?

Answer. I remember two of the type I described and possibly two or three of the subsequent type.

52. Recross-question. Were all of these furnished with two-element bulbs?

Answer. No; the subsequent sets which were gotten from the Marconi company had three-electrode valves.

53. Recross-question. In your testimony in the DeForest case, concerning the apparatus used in these tests, you referred to it as furnished by the Marconi company. Have you any reason to believe that that testimony is incorrect?

Answer. No; it probably is a fact that the Marconi company furnished the sets. Whether by purchase of the Navy Department or by an attaché abroad or as a loan I do not recall at the present time. I undoubtedly can find data to this effect in my files, but I have not thought of this matter for many years.

54. Recross-question. Then, so far as you recollect, the only time a two-element bulb was tested by the Navy was the test which you made on the one Bellani-Tosi direction finder set furnished by the Marconi company, which set included the two-element bulb; am I right?

Answer. That is the only test I made of the two-element valve during my association with the Navy Department.

55. Recross-question. How many two-element bulbs were furnished with this Bellani-Tosi direction finder set?

Answer. Few; possibly half a dozen.

56. Recross-question. Did you use all of them?

Answer. I remember that one was burned out from previous use when I got the set, but I tried all the others. That would be the only way in which such a test would be made to obtain the average of all available units.

57. Recross-question. Were any of the bulbs burned out during or as a result of the test?

Answer. You mean the test I made?

58. Recross-question. Yes.

Answer. No; I do not recall any.

59. Recross-question. In your testimony in the DeForest case, quoted in X Q. 15 of this case, you were referring to

the same two-element bulb as was tested with the Bellani-Tosi direction finder set, were you not?

[fol. 406] Answer. Yes.

60. Recross-question. It is true, is it not, that in all of the DeForest apparatus purchased by the Navy from the DeForest company the audio-frequency amplification was used exclusively?

Answer. The devices in which these DeForest valves were used were the types known as audio-frequency amplifiers, and their practical function was to make louder in the receiving telephones any signal which ordinarily would be heard with less intensity if the receiving telephones were in the detector circuit only.

61. Recross-question. In the DeForest case you testified as follows, did you not?

"Q. Would this amplification depend upon whether the bulb is receiving radiofrequency from the antennae, or audio frequency from a detector device, or will it amplify equally well in either case?—A. The audion amplifier will amplify equally well, speaking generally, whether or not the radiofrequency energy is being amplified or whether the audio-frequency signal from a detector is being amplified. In all the DeForest apparatus which we purchased from the DeForest company the audio-frequency amplification was used exclusively, the reason being that radio technic had not advanced to the point of using radiofrequency amplification. To-day the tendency is entirely in the other direction."

Answer. Yes; my testimony, I wish to make very clear at this point, was entirely with reference to practical use of actual apparatus, and with no reference to the theoretical. In referring to audi-frequency amplifiers and radiofrequency amplifiers I was referring then and am referring now to the specific pieces of apparatus whose trade names are audio amplifier and radio amplifier.

62. Recross-question. Can you produce any adopted or authorized system of nomenclature or standard names adopted while you were in the naval service, or the later one adopted by the Radio Corporation?

Answer. Yes; I have these in my files. I have not these with me, but can produce them from my files. The Radio Corporation list is a standard nomenclature list, giving the standard names for various units which are often incor-

rectly named, and I am not sure whether any definitions are given or not. I can produce copy of definitions which I got up for the Navy and those which I worked on with the I. R. E. standardization committee.

63. Recross-question. Can you state at this time the substance the definitions which you got up for the Navy for the words "detector" and "amplifier"?

Answer. There were a number of different papers of the Navy Department where definitions were given, ranging from early days to later days, and I will be giving more accurate information if I quote from all of these which I can find.

64. Recross-question. Can you state the substance of the first definition of detector which you got up for the Navy?

Answer. I prefer to quote from actual data which I can obtain. The first definition of detector, I recall for one thing, was "tied up" with the idea of crystal detector only, as that was the only detector in standard use at that time. I think this was somewhere around 1912.

[fol. 407] 65. Recross-question. According to the copy of the record in the DeForest case, you gave your testimony in January, 1920. Does that coincide with your recollection of the approximate time when that testimony was given?

Answer. Yes, it was shortly after I came with the Marconi company in June, 1919.

66. Recross-question. Up to that time you used the term detector in the limited sense of meaning a rectifying device did you not?

Answer. The term was loosely used by a great many engineers including myself, as sometimes meaning rectifier and sometimes meaning detector system complete. I remember that in 1921, in conferences on the standardized terms with former members of the Navy Department and with the General Electric, this question came up in connection with the definition of "system" as opposed to unit. I think that prior to that time I used the term very loosely.

67. Recross-question. Can you not answer my question directly?

Answer. Where I was referring to any comparison with some other device, it was a rectifier only—yes. Where I was referring to a complete system, I may have and probably did use the term in the other sense.

68. Recross-question. And in the De Forest case and in this case where you have referred to apparatus as detectors, you have used the term "detector" in the sense of meaning a rectifying device, have you not?

Answer. In referring to the actions which went on in the valve, my testimony at any time up to 1921, would have referred to the rectifying characteristics of the two only. One rule I always tried to keep in mind was to keep one thing in mind in making a comparison between any two things. This led me to distinguish between the detector action, or rectification of a tube and its possible amplification quality, in that the first was the thing which could be directly compared with some other device wholly a rectifier, in my opinion, such as a crystal. But where I referred to a piece of apparatus as a detector, this meant the physical apparatus with whatever total functions it might possess.

69. Recross-question. Can you state the substance of your definition of the term "amplifier" as adopted by you for the Navy?

Answer. Since I can produce the actual definition, I prefer to be accurate by quoting from it. The substance as I recall it now would be a device which, placed between the device which changes radio signals into audio signals would make these audio signals louder and make their effect on some visible or audible instrument greater. This definition referred to physical apparatus, namely, an amplifier as a device which the Navy would purchase or issue from stock, whereas a vacuum tube alone might be termed an amplifier, my definition was entirely as to apparatus which we would purchase, or the operators would use in service.

70. Recross-question. And is that the sense in which you used the term "amplifier" or "amplification" in your testimony in the De Forest case and in this case?

Answer. Not necessarily—where I was referring to apparatus, referring to an amplifier as a physical complete piece of apparatus, that would be the sense. Undoubtedly, [fol. 408] in all my testimony I have occasionally referred to a vacuum tube itself as being capable of use for amplification and hence being in one sense an amplifier. Those were definitions of apparatus.

71. Recross-question. Did you not in the De Forest case and in this case use the term amplification in the sense of meaning to make louder a signal which already exists from some detecting source?

Answer. Except where I referred to radio amplification; yes.

72. Recross-question. In the De Forest case you testified as follows, did you not?

"Q. The crystal detector is still in use?—A. The crystal detector is still in use, greatly in use.

"Q. What is the limit of its use, generally?—A. The crystal detector is used exclusively for reception of spark signals, and to some extent for radiotelephony.

"Q. Is it of any use for amplification purposes?—A. No; it is not.

"Q. Is it capable of amplifying at all?—A. Your question can be answered only in general terms. We use the word amplification in the naval service in the purely practical sense of making louder a signal which already exists from some detecting source. Taking that meaning, the crystal detector is not capable of being used as an amplifier."

Answer. Yes.

73. Recross-question. If the tubes which you have testified were used by the Navy had not possessed the ability to amplify in the sense in which you have used the term amplification, would they have been capable of use for regenerative purposes or for sending purposes?

Answer. That is a question calling for theoretical and expert reply, and I therefore do not wish to answer it. I am desirous of giving full information as to the actual apparatus used by the Navy Department, for which I prepared a great majority of the specifications, and the use of such apparatus which I, as a qualified operator, used or many of the operating instructions for which I prepared. My work in the Navy did not extend to theoretical matters.

74. Recross-question. In your direct examination in answer to Q. 7, you seemed to have no difficulty in giving your opinion that vacuum tube receivers and transmitters were an indispensable part of the naval service. Will you state the facts on which you based your opinion?

Answer. My opinion is based upon actual observation and participation in the field of radio communication before and after the introduction of the various functions of the vacuum tube, and upon my knowledge, based on instructions from my superior officer, and on my own use in the service of the needs of the Navy communication system. My testimony was further based on the actual performance

of the different types of valves in the use for which they were purchased. It does not extend to theoretical consideration of what other things might have been done with the tubes.

75. Recross-question. Could you not have accomplished with crystal detectors, for example, all that was accomplished by the vacuum tubes?

Answer. No, sir; because never, to my knowledge, was the crystal detector capable of use in an amplifier or as an oscillator. I did know a vacuum tube which would perform these functions, used them, and made recommenda- [fol. 409] tions to the bureau as to their suitability in the service.

76. Recross-question. Since you say that the crystal detector could not have accomplished what the vacuum tubes did, because the crystal detectors were not capable of use in an amplifier or as an oscillator, does it not follow that if the vacuum tubes had not been capable of use as amplifiers or as oscillators they would have failed to accomplish the results which you say in answer to Q. 7 they did accomplish?

Answer. That again is a matter of definition. For example, if a vacuum tube, a single tube, is placed in a detector circuit and the device is used in connection with a variable feed-back circuit we get very remarkable effects. For example, we get very much louder signals than if a crystal-detector system were used. According to the I. R. E. definition, and the definition which I now adhere to, this entire device is a detector system, in that it is a single device which makes the radio signals in the receiver audible to the operator. From this viewpoint vacuum tubes as used in a detector system are very valuable features in radio communication, and such a device as I have outlined is one of the great advances in the radio art since the days of the crystal detector.

77. Recross-question. Now, can you answer my question?

Answer. No; your deduction is not correct.

78. Recross-question. Wherein is it incorrect?

Answer. In that there are three major ways in which vacuum tubes are capable of use—in a detector system, in an amplifier, or in an oscillator. You refer to the latter two only. The first is, in general, of equal importance, and had tubes been used for this purpose only they would have accomplished part of the results which I state in question 7.

The amplifier made long-distance work possible, but the type of detector which I have outlined is also very suitable for this work and renders very much greater distances possible than in the preceding art. It is a question of degree. The amplifiers made extreme long distance possible. The detector system I have outlined makes great improvement over the prior art, though it does not go as far as the amplifier. As far as the part of my answer to Q. 7, which refers to oscillators, is concerned, then that part of your question 76 is correct.

79. Recross-question. Is it not true that unless the vacuum tube would amplify or oscillate it would have failed to accomplish substantially more than was accomplished or could be accomplished by the crystal detector?

Answer. As an oscillator, yes; but if it had not been used at all in any amplifier apparatus but only in a detector system, as I have previously outlined, it would have represented a very considerable advance over the crystal art.

80. Recross-question. And even in the detector system, to which you have referred, you have assumed the use of a tube which is capable of amplifying, have you not?

Answer. I am referring to a tube which was bought by the Navy and issued by the Navy for use in a detector system, and so termed. I am not going into the theoretical discussion of the term amplification and am merely referring to the fact that when the Navy sent out amplifiers it sent amplifier tubes to work with them, and when it issued [fol. 410] detector systems the bulb used in this was a detector bulb, and was so called. Such a system, as I said before, is capable of giving much better results than the prior art.

81. Recross-question. Is it not true that the so-called detector tube to which you are referring is a tube which amplifies.

Answer. It is a tube which is in general capable of being used in an amplifier, with greater or less efficiency, depending on characteristics and the purpose for which it was bought.

82. Recross-question. Will you state the type designation of the tube, so that we can identify it?

Answer. One name was the type of a vacuum tube supplied by the De Forest company in 1914 and termed by them the 'audion."

83. Recross-question. That was a three-element tube?

Answer. Yes, sir.

84. Recross-question. Is it not a fact that you, in your advisory capacity, would never have recommended or urged the use of these vacuum tubes by the Navy unless you had been satisfied that they would amplify?

Answer. That general statement is not correct. I recommended the use of the audion as an oscillating device because it gave us a good way of receiving continuous wave signals. A little later, possibly the same time, I recommended the use of the amplifier, because it enabled us to get louder signals than before. Later I recommended the use of the detector system, which I have just testified about, for the definite reason that it worked as a better detector and that we could get louder signals with one bulb than we could get with two or possibly three in an amplifier alone. I recommended the use of the vacuum tube at three different times, the first two being almost coincident, on account of the three different functions which it carried out.

85. Recross-question. You know, do you not, that the tube would neither oscillate nor give louder signals unless it did amplify?

Answer. It would not give louder signals unless it did amplify. The question of the amplifier being essential for oscillation is one for an expert to testify on. This matter did not enter at all into my recommendations for use of the device in the Navy. I prefer not to express a technical opinion on this matter.

Re-redirect examination:

86. Redirect question. When you stated that the audio-frequency amplifiers were used to increase the strength of signals which had already been detected and which already existed, did you mean that they had already been put in such condition that they could be copied and read by the operators before passing through the amplifiers?

Answer. Not necessarily so; where the initial signal delivered by the detector system was too weak to copy this would not be the case. In general, however, the effect of amplification was to make it easier for the operator to copy. My experience is that with concentration in almost every case you could read the original signal, and read it better after amplification.

87. Re-redirect question. Imperfection detection might have been had without the amplifiers?

Answer. Yes.

[fol. 411] The examination by counsel being concluded, the witness in compliance with the rule of the court requiring him to state whether he knows of any other matter relative to the claim in question, and if he does to state it, says he does not.

Deposition of Frank N. Waterman (recalled), for claimant, taken at New York, N. Y., on the 15th day of December, A. D. 1922, and subsequent dates.

Mr. Waterman, in response to interrogatories by counsel for plaintiff, testified as follows:

1. Question. Have you read the testimony of George H. Clark herein?

Answer. I have.

2. Question. Will you please compare the radio telephone sets described by Mr. Clark and shown in plaintiff's Exhibit No. 116 with the invention of the Fleming patent in suit, particularly as set forth in claim 1?

Answer. Exhibit No. 116 shows schematically four vacuum-tube transmitters having specifically different circuit arrangements but all utilizing the same properties of the vacuum bulb, namely its capacity to produce the currents giving rise to the wireless waves. This property of the tube is ordinarily designated as its capacity to oscillate, and when operating in this way the tube is said to be oscillating or in a state of oscillation. It was demonstrated to Judge Mayer in the DeForest case by demonstrations made in court with the apparatus that the device of the Fleming patent was capable of generating oscillating currents when used in the identical arrangement shown in the patent, a battery being inserted, of course, to furnish the necessary energy. It is this function of the vacuum tube that is employed in the arrangement shown in plaintiff's Exhibit No. 116. I believe that I have already referred to this function of the tube when provided with three internal elements, in my former testimony, in considering the so-called ultra-audion, which makes use of this same property in a receiving apparatus. In exercising this function, it will of course be understood that the tube is not in any sense generating

or furnishing energy. It is merely transferring energy delivered to it in a modified form. When performing the receiving function, as specifically described, in the Fleming patent, the bulb receives oscillatory current and delivers direct current capable of actuating the receiving instrument. In a transmitting circuit, conversely, the tube is receiving direct current and delivering in the form of oscillatory currents. In either case the currents have to be furnished to the bulb, and which ever kind is delivered to the bulb is by it transformed to the other kind; thus, the one function is the converse of the other. Thus, in the diagram Figure 1 of the patent, oscillatory current received by the antenna MO is delivered through the transformer MK to the bulb and it in turn produces through the indicating instrument L direct current, capable of actuating the in- [fol. 412] dicator L, although the original current delivered to it was incapable of actuating the indicator. Conversely, if a current from a battery is delivered to the bulb, as for example by inserting it into the conductor J, then the bulb will deliver through the transformer KM pulsating energy to the antenna NMO, resulting in the production of wireless waves radiated by the antenna, as the result of the oscillatory current delivered to the antenna NMO. In the several circuit arrangements of Exhibit No. 116, the bulb T is in each case furnished with direct current by a battery, that is, by a source of energy typified by the battery E^2, and it delivers this energy to the antenna in the form of oscillatory current with the result that wireless waves are radiated.

In the court demonstrations made before Judge Mayer in the De Forest case it was demonstrated by working apparatus that the bulbs of the Fleming patent, which had been made for a detector—that is, receiving—purposes, would oscillate and furnish oscillatory currents when direct currents were supplied to them, and in a variety of circuits, including that specifically shown in the patent. The vacuum-tube transmitters, referred to by Mr. Clark, are merely instances of the application of this property, the particular bulbs employed for the purpose being three-element bulbs, which, in small sizes at least, are more easily controlled than are the two-element bulbs.

It is characteristic of all of the transmitters shown by Mr. Clark that each contains a vacuum tube or bulb, which,

in the language of the Fleming patent, is a vacuous vessel. Within the bulb there are two conductors—in fact, three, lettered, respectively, F, G, and P. Associated with each tube is a source of current acting as a means for heating the conductor F. This is typified in the drawings by the battery B^1. There is also in each circuit outside the vessel, connecting the two conductors. There is, in fact, in each of these transmitters such a circuit for each of the two cold elements. As I have explained, the three-element bulb differs from the two-element bulb in having two cold elements insulated from one another and adjacent, but not touching, the incandescent filament instead of only one, as in the Fleming patent. This provides the means for separating the two functions and exercising them in two circuits. This is done in each of the four transmitters illustrated by Mr. Clark. Thus in the arrangement marked "De Forest," in Exhibit No. 116, the element P of the tube T has a circuit formed by a wire leading therefrom to the upper end of condenser C″ to the earth and thence, as explained by Mr. Clark, through the capacity of the apparatus itself with respect to the earth back to the filament F. The grid circuit passes from the grid G to the upper end of the oscillatory circuit c^2 c^3, thence from the lower end of that circuit to the upper end of condenser c^2 and leak resistance L, and thence from the lower end of this combination back to the filament. The antenna circuit is indicated at A and is connected to the earth at E. Thus all of the elements referred to in claim 1 are present in this transmitter.

The transmitter indicated by the diagram marked "General Electric No. 1" similarly comprises a vacuous vessel containing the two cold elements G, P, and the filament F is provided with means for heating the filament indicated at B^1. The cold element P and filament F are connected [fol. 413] outside the vessel by the wire shown passing through coil d^2, connector 2, and battery B^2. Similarly the grid element G is connected to the filament F through the coil g^3, connector 3, and condenser and leak combination c^1 L. The antenna is indicated at A as before. Thus this transmitter also combines the combination of elements described in claim 1.

Referring to the diagram of Exhibit No. 116, marked "General Electric No. 2," this is substantially identical with General Electric No. 1, the only apparent differences

being that the coil d^2 is in parallel relation through the condenser c^2 with the battery B^2 instead of in series therewith and that the coil marked d^1, corresponding in its circuit relation with coil d^3 of General Electric No. 1, is included in the antenna circuit. The combination recited in claim 1 in the Fleming patent is therefore equally found in the transmitter General Electric No. 2.

The diagram illustrating the Western Electric transmitter, on Exhibit No. 116, only differs in that the coupling is electrostatic instead of electromagnetic, as has been explained by Mr. Clark. There is the same vacuous vessel T, containing cold elements 2 and 3, and the filament F arranged to be heated to incandescence by a source of energy d^1. The plate P is connected by a circuit outside the vessel to the filament through the coil g and condensers c^1, c^3. The cold element g is similarly connected to the filament by way of the condenser g, 4, shunted by the leak L. The antenna is again indicated at A.

There is thus found in each of these transmitters the combination elements recited in claim 1 of the Fleming patent associated in the same way to produce the reversible function performed in the device of the Fleming patent, as demonstrated to Judge Mayer in the De Forest case.

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3. Question. On what did you base your statement regarding the demonstration made before Judge Mayer?

Answer. On the fact that I made them. That is to say, testifying as a witness before Judge Mayer, I was called upon to make and did make the demonstrations referred to. I was assisted by Mr. R. A. Weagant.

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4. Question. Will you compare the receiver referred to by Mr. Clark, as being arranged with terminals with any form of detector and shown schematically in this drawing, Exhibit No. 113, with the invention of Marconi patent in suit No. 763772?

Answer. The receiver shown in Exhibit 113 comprises an antenna circuit having therein an adjustable condenser h^1 and an adjustable inductance j^1, which also serves as the primary of the receiving oscillation transformer; the secondary circuit has the inductance j^2 serving as the sec-

ondary of the oscillation transformer and the variable con-
[fol. 414] denser h^2. There is also in the antenna circuit and the secondary circuit additional variable inductance described by Mr. Clark, but not shown. These constitute additional tuning means. No local indicating circuit is shown, but terminals marked RA RE are shown, whose purpose is to permit the connection to the apparatus of any desired detector and indicator system.

It will be seen that the receiver is substantially identical with that which I have already fully described in making a similar comparison with the apparatus of the Wireless Specialty Co., illustrated in plaintiff's Exhibit No. 87, the testimony beginning on pages 381 and 421 of the manuscript record. The comparison which I there made applies fully to apparatus of Exhibit No. 113. I request that it be understood as applying to this exhibit without repetition.

Exhibit No. 113 also contains an additional coil h^3 connected to two binding posts marked "Tickler." The presence of this coil does not in any way alter or modify the operation of the remainder of the apparatus shown. It is merely a coil sometimes used in connection with the particular type of detector known as the three-element vacuum-tube detector, or audion, and may or may not be used with that detector at the pleasure of the operator.

5. Question. Will you now please compare the receiver described by Mr. Clark in paragraph seven of his answer No. 2, and shown in drawing, Exhibit No. 114, marked "Vacuum-tube receiver arranged for both operation and regeneration," with the invention of the Marconi patent No. 763772, and of the Fleming patent No. 803684?

Answer. The arrangement of apparatus shown in Exhibit No. 114 is identical with that shown in Exhibit No. 113, considered in my last answer, with the addition thereto of a three-element vacuum-tube detector and indicating instruments R. Everything that I have said with respect to Exhibit No. 113 applies therefore to Exhibit No. 114 and I will make the same request that I made that the full description and comparison of the Marconi patent inquired about, which I have given with respect to the Wireless Specialty Apparatus Co.'s receiver, be understood as made with respect to that of Exhibit No. 114.

The vacuum tube detector T is connected in circuit in the manner already described by me in my former testimony in answer to Q. 34, with reference to Exhibit No. 83, drawing

PN audion, and plaintiff's Exhibit No. 82, De Forest PN audion, and also as referred to in plaintiff's Exhibits Nos. 71, 72, and 74.

This circuit of Exhibit No. 114 shows in addition the leak resistance L and the tickler coil j^3. These elements, however, in no way alter the application of the testimony given in answer to Q. 34, since the leak resistance L is merely a means of increasing the sensitiveness of the device as a detector and maintaining stability of operation, while the coil j^3 serves to enable the coil to function not only as a detector but as a regenerative amplifier. I will ask that the description and comparison which I have already made of such a structure with the Fleming patent in suit in my answer to Q. 34 be read as applying also to the apparatus of plaintiff's Exhibit No. 114.

6. Question. Please compare the direction finder described by Mr. Clark in paragraph 10 of his second answer, and shown in his drawing, Exhibit No. 115, with the invention of Marconi patent 763772 and with the invention of the Fleming patent 803684.

[fol. 415] Answer. The direction finder shown in plaintiff's Exhibit No. 115 comprises an ordinary coupled circuit receiver, such as is shown also in Exhibits Nos. 113 and 114, just considered, having associated with the secondary circuit thereof an additional antenna circuit of the loop form. The antenna A contains, as in the other exhibits referred to, a variable capacity h^1 and a variable inductance j', as tuning elements and the secondary circuit comprises the oscillation transformer coil j^4, and the tuning condenser h^2. It also has the inductance j^2, constituting the secondary of the oscillation transformer, whose primary j^5 is connected in circuit with the loop antenna LA, this circuit also containing the variable condenser h^3.

In use the antenna A is tuned to the wave length of the incoming signals and the secondary circuit is tuned to the same wave length. There are therefore the two receiving circuits of the Marconi patent inquired about and this much of the apparatus constitutes a distinct receiving apparatus for any desired use. The association therewith of the loop antenna LA enables it also to be used for dir ction finding purposes, so that the direction from which a received signal is arriving can be ascertained. This added association and function in no way alters the normal organization and function of the antenna system A and the secondary cir-

cuit. Associated with this secondary circuit is a three-element vacuum-tube detector and signal-indicating device, exactly as in Exhibit No. 114, and I will ask that the answer which I have given as to Exhibit No. 114 in my last preceding answer be understood as applying to Exhibit No. 115.

7. Question. Will you please explain the relation of the wave charge referred to in paragraph 16 of Mr. Clark's answer to Q. 2 to the Marconi patent No. 762773?

Answer. In a transmitter wherein a primary condenser circuit containing a spark gap is associated with a radiating antenna circuit, it is essential to the effective operation that the two circuits should be tuned to resonance the same wave length as set forth in the Marconi patent, as I have already explained in my former testimony. It is frequently desirable that the same transmitter should be able to transmit more than one wave length, but in order that this may be done, it is necessary to change the inductance or capacity or both in each of the two circuits in order that the resonant relation may be maintained. For the proper operation of the spark gap it is also desirable that the coupling—that is, the association of the two circuits in their relation to one another—may be maintained. The wave changer referred to by Mr. Clark is simply adjusting means associated with the two circuits of the transmitter, whereby an operator may by the single movement of a switch arm or control means simultaneously adjust both of the circuits so that they will be in tuned relation for any one of a number of wave lengths for which the wave changer is arranged. It would thus be possible for the operator at will to select the wave and to tune the apparatus to any one of a number of wave lengths, as, for example, 450, 600, and 750 meters.

In this way an operator could avoid interference with other stations. In general, therefore, the wave changer is an apparatus applied to a transmitter, such as is described in the Marconi patent, for enabling the tuning of the two circuits to be more readily performed. Or, putting the matter in another way, the tuning to any one of several [fol. 416] wave lengths as required by the Marconi patent is effected initially and by the aid of this switch is automatically preserved for any wave length for which the transmitter is adapted.

8. Question. Please explain the relation of the spark set vacuum-tube excitation referred to by Mr. Clark in paragraph 4 in answer to Q. 2 to the Fleming patent.

Answer. It appears from Mr. Clark's testimony that certain two-circuit spark transmitters were modified by removing the spark gap and associating with the remainder of the apparatus the necessary vacuum tube to convert the transmitters into oscillating vacuum-tube transmitters of the class I have already considered in comparing the structures of Exhibit No. 115 with the Fleming patent. Referring, for example, to diagram marked "General Electric No. 2" of Exhibit No. 116, it is evident that the spark transmitter would have the necessary oscillation transformer, such as d^1, d^2, and the loading inductance *gxd*, and would also have the source of current typified by the battery b^2 and condensers such as c^2. Associating with these, the bulb such as T would convert the apparatus into an oscillating vacuum-tube transmitter, such as I have already fully considered in my answer to Q. 2 of this deposition. I will ask that that answer be taken as applying to these transmitters inquired about.

9. Question. In view of the objection to your testimony regarding what transpired before Judge Mayer in connection with the demonstration of the oscillating capacity of the two-element valve, I will ask you if you can produce a copy of the record of that particular trial.

Answer. Yes; I produce a copy of the record as reported in that case and including the testimony with respect to the demonstration as to which I have testified.

Mr. Peters. I request that this testimony be marked for identification and I offer it to defendant's counsel for such use as he may see fit.

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Cross-examination.

By Mr. Edwards:

10. Cross-question. At the time of the so-called demonstration before Judge Mayer to show that a two-element bulb which would detect would also oscillate, did you inform Judge Mayer that such oscillatian as you obtained was due to the presence of gas in the tube?

Answer. No representation was made to Judge Mayer that any bulb that would detect would oscillate nor was any made as to the cause of the oscillation as I did not know the

cause and do not now except as it is a result of the capacity of the bulb to amplify resulting in some way from the electron discharge.

11. Cross-question. Do you now say that you do not know that such oscillation as you obtained before Judge Mayer was due to the presence of gas in the tube?

Answer. Yes; I do. My recollection is that voltages as high as 150 volts were used and that the bulbs gave no indication of ionization phenomenon and the bulbs were as [fol. 417] highly vacuous bulbs as the Marconi company was able to produce at the time they were made and I am confident that they are higher vacuum tubes than could have been produced at the date of the Fleming patent.

12. Cross-question. Was the 150 volts just referred to the plate voltage?

Answer. I do not assert the 150 volts as other than my present recollection. If I remember rightly, a considerable number of different bulbs were used at the several tests which were made during the trial, and if my memory serves me the voltages ran from about 90 to 150 volts. The voltage referred to is the plate voltage; that is, the voltage between the plate and the filament.

13. Cross-question. What filament voltages were used?

Answer. My recollection is that it was about 6 volts; certainly not over 12.

14. Cross-question. Do you say now that you do not know that if the bulbs shown Judge Mayer had been bulbs with a vacuum of the degree now obtainable that the bulb would not have oscillated?

Answer. Yes; I know that it is not easy to make small bulbs with the high degree of vacuum obtainable at the present day oscillate when they have only two elements. I also know that larger bulbs will oscillate much more readily.

15. Cross-question. Will you state the order of the vacuum obtainable at the time of the Fleming patent and that attainable to-day?

Answer. I doubt if I can do that. I can give you my recollection if you wish, but as the question goes to a matter of fact I would rather confirm it. My impression is that about ten to the minus third power millimeters represented a high vacuum at the date of the Fleming patent; perhaps ten to the minus seven to-day.

16. Cross-question. What is the order of the vacuum of the incandescent lamp at the date of the Fleming patent?

Answer. Somewhere in the vicinity just stated; I have no closer knowledge.

17. Cross-question. That would be in the order of ten minus three millimeters?

Answer. That is my present impression; but, as stated, I would prefer to look the matter up.

18. Cross-question. Are you prepared to say with your present knowledge that if the bulb or bulbs demonstrated before Judge Mayer by you had had a vacuum of the order of ten to minus seven power it would have oscillated?

Answer. Since I do not know exactly what the vacuum was in the demonstration above and have not made sufficient tests with bulbs of definitely measured vacuum, I am not prepared to say whether they would or would not in that particular size.

19. Cross-question. Is it your belief that the bulbs demonstrated before Judge Mayer would have oscillated if these bulbs had been high vacuum bulbs?

Answer. My understanding is that the bulbs were what we call high vacuum bulbs at the present day, although not presumably the highest vacuum obtainable at present. As to whether they would oscillate if they had been different from what they were I can not say, but my belief is that it is highly probable that two-element bulbs with [fol. 418] the highest obtainable vacuum will be the bulbs ultimately used in high power bulb installations.

20. Cross-question. Are you prepared to say that such oscillation as you obtained before Judge Mayer was due solely to the electrons and was not due to such gas characteristics as the tubes may have had?

Answer. Of course, it was due solely to the electron discharge as the primary cause. I do not think anyone would undertake to say that there are no ions other than electrons present in any bulb, no matter how high the vacuum, or that they may not be secondary causes of what goes on. I certainly do not say so.

21. Cross-question. Then you do not assert that such oscillation as you obtained before Judge Mayer was not due to the gas characteristic of the tube, do you?

Answer. I do not assert either that it was or was not, but only that there was no evidence that it was.

22. Cross-question. Is it your belief that if these tubes demonstrated before Judge Mayer had had no gas charac-

teristic that oscillation would nevertheless have been obtained?

Answer. As I have said, I can not say what the bulbs would have done if they had been different. I can only say that my belief is that the highest present-day vacuum does not defeat the oscillation of the two-element bulb, although they do not oscillate readily in small sizes.

23. Cross-question. Do you now say that you do not know that if these tubes exhibited before Judge Mayer had had no gas characteristics you could not have obtained any oscillation therefrom?

Answer. Yes; I do say that—I have already said it.

24. Cross-question. Was the bulb, or any of the bulbs, exhibited to Judge Mayer and demonstrated before him similar to the bulb in evidence in this case and marked "Plaintiff's Exhibit No. 29"?

Answer. No; a flat plate was used for the cold element instead of a cylinder.

25. Cross-question. Can you make a sketch showing the type of bulb which was used before Judge Mayer?

Answer. Yes; I offer you such a sketch, made roughly in pencil. This illustrates the general construction and approximate size.

Mr. Edwards. The sketch is offered in evidence as defendant's Exhibit No. A.

26. Cross-question. Can you produce any tubes similar to those which you say were demonstrated before Judge Mayer and which will oscillate?

Answer. I have none in my possession and do not know whether or not those used or others like them are still in existence.

27. Cross-question. Will you endeavor to procure some from the claimant and report to us at a future session?

Answer. I will be glad to endeavor to obtain one. I have no idea whether or not I shall succeed.

28. Cross-question. How many of the bulbs were demonstrated before Judge Mayer?

Answer. I don't know—if I ever did know I have forgotten. I remember that I had several—perhaps half a dozen at court and that several of them were used. One was found to show traces of ionization and was discarded, and the others were used thereafter.

[fol. 419] 29. Cross-question. Were all of the bulbs operated at the same voltage during the time they were oscillating?

Answer. I don't know just what the question means. I remember that when the same bulbs were operated at a given time the same voltage was not necessarily employed, but in general all that was done was to stop the operation by disconnecting the filament current and simply relight the bulb when it was desired to have the operation begin, and naturally no change was made in the voltage in the plate circuit. In other words, to demonstrate that it was oscillating and that the cause of the sound heard was not due to some other cause, the filament of the oscillating was disconnected from its lighting battery and connected again as often as desired by Judge Mayer or counsel and experts.

30. Cross-question. In order to get the several bulbs into oscillating condition it was, I take it, necessary to adjust the plate and filament voltages for that bulb, was it not?

Answer. Yes; it was necessary. These particular bulbs were experimental bulbs made for detecting purposes and had different separations between the plate and the filament. They would, in general, call for different plate voltages in use for any purpose.

31. Cross-question. Do you mean that the separation between plate and filament was different as between the several bulbs which were exhibited before the court?

Answer. Yes. These bulbs were taken from a number made in the course of a study of two-element bulbs some years before the demonstration in court referred to and in general were made with varying separation of the elements. They were made in the particular shape illustrated because it was an easy form in which to obtain approximate accuracy of the desired separation.

32. Cross-question. After you adjusted each bulb to the particular plate voltage and the particular filament voltage necessary to put the bulb in an oscillating condition, were these voltages left unchanged during the entire time that particular bulb was being demonstrated, excepting, of course, the making and breaking of the filament circuit for the purpose of starting and stopping the operation?

Answer. I can not positively assert that such was always the case; certainly it was in general. I remember that one or more bulbs were tried—I think not in court, but for some one on the other side—Professor Stone, I think—over

a considerable range of voltage, perhaps twenty or thirty volts, I do not now remember, but I can not now say that that was done for Judge Mayer's benefit or that it was not done. There were a good many tests made and in general the voltage on the plate circuit was not changed, but the filament was made and broken.

33. Cross-question. What is the longest period of time during which any one of these bulbs continued to oscillate in the demonstration before Judge Mayer?

Answer. I do not remember; not very long I should say. I do not think at any time over half an hour; perhaps not more than 15 or 20 minutes.

34. Cross-question. Do you think that any one of them oscillated as long as 15 minutes during the demonstration before Judge Mayer?

[fol. 420] Answer. I can not swear to it, but I have no doubt of it. My recollection is that in general the demonstration referred to was made for Judge Mayer, and after he had finished his observations then counsel on both sides and the defendant's experts and witnesses listened, and I have no doubt that in more than one instance the time consumed was more than 15 minutes; also after testimony was resumed the court adjourned in one or more instances, the bulbs continued in use while defendant's witnesses were testifying.

35. Cross-question. And is it your recollection that during this 15 or 20 minutes the adjustment of the plate and filament circuits remained as originally set?

Answer. I have no doubt that they did on one or more occasions but I do not think they always did—my recollection is that at least on one occasion the voltage was varied purposely for the benefit of Doctor Stone or some one representing the defendant.

36. Cross-question. What is the longest period of time during which any one of these bulbs oscillated before Judge Mayer without readjustment of plate or filament voltages?

Answer. As already stated, I do not know.

37. Cross-question. Have you any recollection?

Answer. None other than I have given—I do not see how the question differs from those already asked.

38. Cross-question. How far apart were the sending and receiving stations in this so-called demonstration before Judge Mayer?

Answer. No measurement was made. It was merely a table demonstration, perhaps 6 feet, something of that order, I think.

39. Cross-question. In your direct examination in answer to Q. 2 you said that this bulb was demonstrated before Judge Mayer in a variety of circuits, "including that specifically shown in the patent." Is this quoted part of your answer literally true?

Answer. Yes; I think so. At least I do not note any inaccuracy on hearing it read. I believe the question does not quote the entire answer.

40. Question. The question is directed particularly to that part of your answer where you say that the circuit specifically shown in the Fleming patent was demonstrated before Judge Mayer. Is that statement literally true?

Answer. Yes; I think so, unless the question intends to distinguish between the quoted part in the present question and the entire answer which, if I remember rightly, states that a battery was employed, as, of course, the tubes could not make oscillations out of nothing. You have to have current supplied to it; in other words, before it could cause that current to oscillate.

41. Cross-question. Then when you say that you demonstrated that the Fleming bulb would oscillate in the circuits specifically shown in the Fleming patent, you mean that circuit with a battery added to it, do you?

Answer. Certainly, I so stated in my direct examination.

42. Cross-question. Well, you took care to make the statement that a battery was used in an altogether different part of your answer from that in which you state you used the circuit specifically shown in the patent, did you not?

Answer. No. The statement which counsel quotes immediately follows the full explanation of the insertion of the battery in the circuit of Figure 1 of the Fleming [fol. 421] patent. The quoted statement being made immediately after the explanation of the need for and function of the battery. Also I call attention to the first paragraph of the answer where I said, "It was demonstrated to Judge Mayer in the De Forest case by demonstrations made in court with the apparatus that the device of the Fleming patent was capable of generating oscillating current when used in the identical arrangement shown in the patent, a battery being inserted, of course, to furnish the necessary

energy." Here the statement quoted is in the same sentence with the statement that the battery was included.

43. Cross-question. Without the battery referred to the bulb of the Fleming patent could not be made to oscillate in any event, could it?

Answer. I should say that it could not, for the same reason that a boiler will not make steam without a fire under it.

44. Cross-question. But the bulb will act as a detector without the battery referred to, will it not?

Answer. No; not if no signal is furnished to it. If energy is furnished to it at either end, so to speak, it will respond.

45. Cross-question. But even if energy in the shape of a signal is furnished to the bulb in the circuit shown in the Fleming patent, without the battery, which you added in your so-called demonstration, the bulb would do no more than detect, would it?

Answer. Without a battery in the plate circuit, the bulb, of course, would only detect when the signal is supplied to it.

46. Cross-question. And under these same conditions the bulb, while detecting, will not amplify, will it?

Answer. It will not.

47. Cross-question. And, using your illustration, a fire is useful for warmth even though it is not under a boiler, is it not?

Answer. I do not get the point of the question. Fire, of course, has many uses.

48. Cross-question. So far as you know, is the Fleming two-element bulb used commercially in wireless telegraphy at the present time?

Answer. I do not know whether it is or not.

49. Cross-question. Did you ever have knowledge of any commercial use of the Fleming two-element bulb in wireless telegraphy or telephony?

Answer. I have never been connected with the commercial business. I remember seeing one in use in a station which, to the best of my recollection, was the Wanamaker store station, and also one in a station operated by the Marconi company, but I have forgotten where it was located, except that it was here in New York. When I say one, I mean a receiver known at that time as a Fleming valve receiver in each of these stations. Each receiver had two bulbs. In each case the receiver was being employed as the commercial means of receiving the signals. I may, perhaps, have seen others, but I never went to

any stations for the purpose of seeing a Fleming valve used; I merely remember incidentally noting these two in use.

50. Cross-question. In all of these instances was the bulb used in the circuit shown in the Fleming patent—that is to say, without the battery which you inserted in the circuit in your so-called demonstration before Judge Mayer?

Answer. I did not notice what the circuit or adjustment employed was.

[fol. 422] 51. Cross-question. Will you identify or make sketches showing the various circuits which you used before Judge Mayer?

Answer. I do not know that I can do that from my recollection at this time. The first circuit used was Exhibit No. 2 in the record before Judge Mayer, the receiving circuit being shown in Exhibit No. 3 in the same record. My recollection is that the next test was the same, except that condenser 3 was omitted and the receiving apparatus was changed by removing the bulb detector and substituting a crystal used without a battery. Of course, the so-called tickler coupling was removed when the tube was removed. I indicate the transmitting and receiving circuits in this test on the sketch that I hand you, marked, respectively, "Sketch A" and "Sketch B." The next transmitter arrangement that I recall was, I think, like sketch C, which I have made, the receiver being the same as shown in sketch B, except that a file and a bit of wire were inserted into the receiving circuit for the purpose of interrupting the oscillations. I should note that in sketch A the element which I mark "K" was a file and a wire arranged to be rubbed over so as to break up the transmitted oscillations.

Another arrangement used I indicate to the best of my recollection in sketch E, but whether it was the next in order or not I do not remember. Sketch E illustrates the receiver in which K indicates a crude type of ticker consisting of a file with a wire arranged to be drawn across.

Sketch F illustrates the last arrangement used to the best of my recollection. It is the arrangement shown in Figure 1 in the Fleming patent plus the energy supplying battery.

I do not assert the accuracy of these, they merely represent my best present recollection.

Mr. Edwards. Defendant's counsel offers in evidence the Exhibits 2 and 3 and sketches A to F, referred to by the witness, and asks to have the Exhibits 2 and 3 marked together as "Defendant's Exhibit B." and the sketches A to F, inclusive, marked together as "Defendant's Exhibit C."

53. Cross-question. Will you indicate on the sketches A to F, inclusive, how the various transmitter circuits were coupled to the antenna circuit, if one was used, or otherwise describe how all of these transmitter circuits, including that of Exhibit No. 2, were coupled to the antenna?

Answer. I do not remember the precise arrangement. My recollection is that we informally agreed with the defendant's expert to use the same arrangement that had been used for a long series of tests in the prior case of Marconi against DeForest wherein the three-element bulb as a detector and amplifier were more particularly in question. If I am right in this recollection then the circuit which in sketch B contains a conventional antenna indication, did not in fact have the antenna but was an artificial antenna coupled loosely to both the transmitter and the receiver. I think the coil 2 in the transmitter was inductively coupled to the antenna circuit indicated in sketch B and in point of fact the coil indicated in the antenna directly below the variable condenser therein was the coupling coil and that it was located some six or eight feet away from the receiver and in inductive relation to the coil 2 of the transmitter.

[fol. 423] 54. Cross-question. Was the antenna circuit conventional represented in sketch B an open or a closed circuit?

Answer. If the recollection stated in my last answer is correct, it was a closed circuit, so far as oscillation is concerned.

55. Cross-question. What was the function and purpose of the induction coil Z in sketches A and C?

Answer. It was primarily an impedance to keep the high frequency out of the battery circuit as used in the circuit of sketch A. I have assumed also in my use of such a coil that it acts as an energy storage device, at any rate, I have used it in general because it seems to facilitate the oscillation of the tube.

56. Cross-question. What part of the circuit of sketches C, D and F, was coupled to the antenna or other circuit to which the receiving circuit was coupled?

Answer. I don't know as to sketch C—I think there was a coupling for the antenna circuit but I can't remember where it was located.

In sketch D, the coil 2 is the same coil as coil 2 in sketch A, and coil Z is absent. The coupling I think was made to coil 2, simply by placing the coupling coil of the receiver in its vicinity, say a foot or two away. The same statement is true as to sketch F.

57. Cross-question. Did the operation of the two electrode tubes, as demonstrated before Judge Mayer, in any way resemble an arc?

Answer. Not that I know of.

58. Cross-question. In the record, marked for identification, after the answer to Q. 9 of your direct examination, I find the following testimony

"40 X Q. Is not in fact the blue glow striking an arc between the two electrodes, when this bulb is generating oscillations, as you say it does, have you not established an arc between the two electrodes?—A. Well, Mr. Darby, I began working with arcs in 1888, and I have not yet heard anyone define one. If you can define an arc to me I can answer your question.

"41. X Q. Will you please answer the question?—A. I do not call that an arc, nor do I call that anything which in any way resembles an arc?

"42. X Q. You say that it does not in any way resemble an arc?—A. Yes; that is my understanding of it."

Did you so testify before Judge Mayer?

Answer. I assume so. I have no independent recollection of just what I said apart from the typewritten record.

59. Cross-question. Are the statements in the quotation in accordance with your present understanding?

Answer. Yes.

60. Cross-question. In the accounting proceedings in the DeForest case, did you testify as follows?

"Q. Do you maintain that all two-electrode bulbs will oscillate in some degree?—A. No; because I do not know whether they will or will not.

"Q. How can you tell whether a given two-electrode bulb will or will not oscillate?—A. By trying it.

"Q. How do you try them?—A. By connecting it in circuit and observing what happens.

[fol. 424] "Q. What does happen?—A. Sometimes it oscillates and sometimes it does not.

"Q. Is there any way to tell beforehand whether it will oscillate or not?—A. Not that I know of.

"Q. If you want to build one in order to make it oscillate, do you know of any feature of construction or other characteristic that should be present in order to insure oscillation?—A. I have not personally followed that branch of the development, that is to say, the design, and I am unable to say. In general, the bulbs, which are mechanically well constructed and whose filaments give off a plentiful supply of electrons, oscillate.

"Q. When you refer to features of mechanical construction, what features have you in mind?—A. That the bulb should be tight and the initial component parts clean, well put together, so as to remain in proper relative position.

"Q. Any others?—A. No.

"Q. What is necessary in order to insure that the filament will give off a plentiful supply of electrons?—A. That the material should be proper and have the property of giving off electron. It is a physical property that is not definable by any other term that I know of.

"Q. Can you furnish us with a characteristic curve of the plate current of the bulb which you demonstrated, or a similar one?—A. No; I have no such curve.

"Q. Could you draw a curve that would approximately illustrate the plate-voltage curve of this valve?—A. No; I could not. I do not remember having seen a characteristic curve of any of them.

"Q. You produced in the main case, I believe, several characteristic curves of different detectors. For example, I call your attention to plaintiff's Exhibit No. 71, at page 2459 of the main record, also page 2485 of the same record and 2467 of the same record. Will you look at these exhibits as reproduced in the printed record and say if the characteristic curve of the valve which you tested was anything like any of those curves [handing book to witness]?—A. I am not able to compare, because I stated I do not remember having seen the characteristic curves of any of those demonstrated and I do not know whether or not they were taken.

"Q. Do you know if any characteristic curves were taken of any of the lot from which the demonstrated bulbs were selected?—A. No; except that I know that when those bulbs

were built some years before, it was the custom in the Marconi laboratory to take the characteristic curves. Therefore, it is probable that the characteristics were taken at the time they were made.

"Q. Did you make any characteristic curves of any of the two-electrode type of Fleming bulbs?—A. If you mean any bulb at any time, yes; I have taken many of them, but if you mean any of the bulbs of that lot, I am not able to say.

"Q. Do you think that you could reproduce, even approximately, the characteristic curve that would be substantially the same as the characteristic curve of either the lamps, the two-electrode bulbs that were tested, or any others of the lot from which they were taken?—A. No; I certainly could not, for reasons already given. In general, the charactertistic curves that I have taken are more [fol. 425] or less like this on page 2459 of the printed record, but I can not assign values to co-ordinates.

"Q. Could you say, from looking at the curves on page 2459, whether or not any of the valves from which these curves were taken would or would not oscillate?—A. No.

"Q. So far as you know, is any particular form of characteristic curve necessary in order that a given two-electrode bulb shall oscillate?—A. I have never investigated the relation between the performance of the bulb in this respect and its characteristic curve, and I do not know whether or not any one else has.

"Q. Can you assign any reason as to why some of the lot of two-electrode Fleming bulbs would detect and not oscillate, whereas others would both detect and oscillate?—A. No; I do not know what causes any of the variations. Some of them are excessively poor even as detectors; that is very unusual. Some of them require a local battery and some do not. I do not know what causes these variations.

"Q. If the two-electrode valve is a good detector, does it necessarily follow that it is also an oscillator?—A. I do not know.

"Q. I take it that I may assume that if the valve will oscillate it will also amplify, may I?—A. I think so; that at least is the general understanding.

"Q. So far as you know, in any two-electrode Fleming valve which which will detect, is any special degree of vacuum necessary in order to make it an oscillator?—A. Not that I know of.

"Q. Is any special kind of gas necessary?—A. No.

"Q. Any special density of gas?—A. Not that I know of.

"Q. Is the presence of a blue glow in the lamp necessary in order to attain oscillation?--A. It is not.

"Q. If present, does it prevent or interfere with oscillation?—A. It behaves as in any bulb. If there is too much, it prevents operation.

"Q. One place in your previous testimony I think you referred to the necessity of having a sufficiently high vacuum in order to insure that a two-electrode bulb would oscillate. Are we to understand that your present view is that a special degree of vacuum is not necessary?—A. The vacuum must be high enough or the devices will not operate as detectors or as oscillators.

"Q. If the vacuum is high enough for the device to act as a detector, does it follow from that that it will also act as an amplifier or oscillator?—A. No; I think not.

"Q. Is it true that the higher the vacuum the more certain will be the prospect of making the two-electrode tube amplify or oscillate?—A. I am not able to answer so broad a question; in other words, I do not know.

"Q. So far as you know, if the vacuum is as complete as it is possible to attain by the most modern methods, does that prevent or interfere with a given two-electrode tube which will detect, also amplifying or oscillating?—A. I am unable to say.

"Q. Have you any reason to believe that the highest attainable vacuum would present oscillation by a two-electrode valve which will detect?—A. No. I have not sufficient experience to generalize.

"Q. In the valves which you found and which you say oscillated, did they oscillate at all voltages or only at some [fol. 426] special plate voltage?—A. I think the answer would be neither; that is to say, I never tested one at all voltages and I never found one that would oscillate only at one particular voltage.

"Q. When you found one that would oscillate at some particular voltage, would it oscillate at all other plate voltages within the range attainable?—A. As I stated, I do not know, as I never tried all those voltages. In the valves tested in court, for example, the same bulb oscillated at different voltages.

"Q. What was the range of voltages used on the same bulbs in the demonstration?—A. I do not remember, but, roughly, probably 80 volts to 140.

"Q. Are we to understand that the same bulb would oscillate equally well within this same range, from 80 to 140 volts?—A. I do not know that there was any perceptible difference. None was apparent to me.

"Q. You did, however, test it at different voltages within this range, did you, the same bulb?—A. I have given my best recollection. I do not swear that that was the range.

"Q. Is it true that according to your best recollection, the same bulb oscillated equally well at ranges between 80 and 140 volts and that the lamp was actually so tested with these different voltages?—A. That is what I have said. I am unable to say. I have said it was tested at different voltages and that it appeared to oscillate equally well at different voltages. My best estimate of the range I gave at 80 to 140.

"Q. Give us your best recollection of all of the different voltages at which any two-electrode bulb was actually tested by you.—A. I can not do better than I have already done."

And also—

"Q. Is it your understanding that any given two-electrode Fleming bulb which will detect must inherently and of necessity also oscillate?—A. I have answered that at least four times.

"Q. Will you answer it again?—A. I do not know that that is so.

"Q. So far as you know, would increasing the degree of vacuum increase the possibility of getting oscillation with a given two-electrode Fleming valve?—A. I do not know over what range that is true. I know that if the vacuum is too poor, that it will not operate at all, and that over a wide range they improve with improvement in vacuum.

"Q. Would it be true that the better the vacuum the more probability there is that the valve will oscillate?—A. I do not know.

"Q. In the two-electrode valves which were tested and found to oscillate did you make any tests as to the length of time they would continue to oscillate?—A. No; that is, I made no exhaustion test. They oscillated long enough

for any observance we wanted to make, and naturally we spent no time merely seeing how long they would keep it up.

"Q. For how long a time did you actually keep it up?—A. I should think the longest I ever saw one bulb oscillate was a few hours, maybe two or three hours."

And also—

"Q. Will you explain how it is possible, even at the present day, to design a two-electrode tube which will have a given amplification constant?—A. I personally do not know.

[fol. 427] "Q. Do you know of anybody who manufactures and sells such a tube?—A. I do not understand that there are any on the market.

"Q. Do you know of any place where the defendant or its representatives, can obtain such a tube?—A. I do not know if the Marconi company is willing to sell or give them away or not."

And also—

"Q. Will you describe the two-electrode tube which you demonstrated before the court in order to get oscillation? —A. The glass bulb was cylindrical, perhaps three-fourths or seven-eighths of an inch in diameter, and contained the short filament in the form of a loop, that is, U-shaped, and a plate which was a simple circular disk mounted with its plane at right angles to the plane and direction of the filament and perhaps half an inch away from the curved portion of the filament.

"Q. Did it have any portion of the circuit exposed outside of the tube?—A. It did not.

"Q. Or anything corresponding to the circuit which you said was outside of one of the two-electrode tubes yesterday when you were testifying?—A. It did not.

"Q. Do you know what kind of gaseous medium was in the tube?—A. None; except what residual air was necessarily present.

"Q. Do you know how much vacuum there was?—A. Only in a general way that it would be classed as a very high incandensecent lamp vacuum.

"Q. Do you know by what means the vacuum was attained?—A. No; except that the bulbs were pumped in an oven with the highest vacuum that could be obtained by best forms of mechanical pump.

"Q. Do you know what kind of pump was used?—A. I do not remember; no.

"Q. Was it a mercury pump?—A. I think so, but I am not positive.

"Q. Do you know where the tubes were made?—A. Yes; they were made by the Marconi company at Aldeen.

"Q. Do you know who would be able to inform us specifically as to how these tubes were made?—A. I think it is found in the record. Mr. Weagant was examined about that.

"Q. Well, I have looked in the record and fail to find out how they were made, and if you can do so, I would like to know someone who had actual knowledge of the way in which the bulbs were made?—A. They were made under Mr. Weagant's direction, and all I know about the matter is that I was familiar with the room where they were made and saw from time to time many bulbs of this general description, and I think of the same lot from which these were selected, made. I know that they were the highest vacuum which the Marconi company was able to obtain at that time and that it was obtained by a series of pumps, the last one of which was a mercury pump, but I am not sure.

"Q. And the other pumps, do you recall what kind of pumps they were?—A. I think there were two mechanical pumps, first a rough vacuum pump and then a pump such as would have been sufficient for ordinary incandescent lamp exhaustion and finally a more refined form of pump.
[fol. 428] "Q. The two pumps of which you speak, were they mercury pumps, if you recall?—A. No. I think the first one was a mechanical pump, but I am not certain; that is, a piston pump.

"Q. Could you produce one of the bulbs for our inspection?—A. No; because I haven't got one.

"Q. Could you reassemble the apparatus and make one of these bulbs oscillate again?—A. No. The apparatus is none of it in my possession.

"Q. What became of it?—A. I don't know. It may be filed in court for all I know.

"Q. Would you be willing to undertake to repeat the experiment and produce oscillation by one of these tubes again, if so directed by counsel for the Marconi company?—A. Certainly.

"Q. You said, I believe, that these tubes were originally constructed for some other experimental work. Can you

tell us the nature of that work?—A. It appears in the record that they were part of a long series of bulbs that were made for the purpose of ascertaining the effect of varying different elements in the construction, particularly, the spacing, that is, the shortest distance between the filament and the plate element. It was for this reason that they were made in the cylindrical form and with the flat plate, so that the distance could always be accurately determined.

"Q. So far as you know, is any special distance between plate and filament essential in order to make the two electrodes essential in order to make the two-electrode tube amplify or oscillate?—A. No.

"Q. Can you state approximately the date when these tubes were originally made?—A. Only in a very rough way. I should guess that it was the fall of 14."

Answer. As to the first quotation, my impression is that there is probably something omitted from the second sentence of the next to the last answer quoted—I presume the word 'more''; further or something of like import was intended to be inserted after the word "say."

With respect to the last quotation I do not know what the second and third questions and answers quoted mean. I assume that the remainder quoted portions are substantially what I said, although apart from the typewritten record I have no independent recollection.

59. Cross-question. Is all of the above-quoted testimony in accordance with your present recollection?

Answer: Yes; in the sense that I have no present recollection in contradiction of it.

60. Cross-question. Will you look at the plaintiff's Exhibit No. 85 and say whether or not in your opinion that exhibit embodies what you understand to be the invention of the Fleming patent in suit when the terminals X, Y, of that device are connected to an ordinary telephone-wire circuit so that the device receives audio frequency current from the telephone wires?

Answer. I have had no experience with such use and do not know whether it would be operative. I can only say that so far as I have considered the use of these bulbs it has been in connection with the receipt or transmission of radio signals.

[fol. 429] 61. Cross-question. Have you any reason to suppose that the device would not be operative to amplify

ordinary telephone currents if suitably connected to the wires of a telephone circuit?

Answer. I do not at present remember enough about the constants of a telephone circuit or the actual wiring thereof to have any opinion. The device shown in Exhibit No. 85, so far as I have any information about it, is used in connection with a radio receiver.

62. Cross-question. You have no opinion about the device except when it is operated by currents of radio frequency?

Answer. I do not know sufficiently definitely just what the question is intended to convey to answer it categorically. My understanding of the device shown in Exhibit No. 85 is that it is in normal use a part of the wireless receiving apparatus—whether just as it stands it has other capabilities or not, I have not investigated and have no information.

63. Cross-question. Assume that the terminals X Y of this device are connected to a crystal detector circuit in which latter circuit radio-frequency current is rectified by the crystal detector and the audio-frequency current from the crystal detector circuit is amplified in the device of Exhibit No. 85. Would the device then embody what you understand to be the invention of the Fleming claims in suit?

Answer. Yes; my understanding is that in the case supposed the crystal detector and three bulbs of Exhibit No. 85, together constitute the complete detector of the assumed receiving apparatus.

64. Cross-question. In both of the illustrations I have given, that is to say, if the terminals in Exhibit 85 connected to a telephone wire on the one hand and the terminals of Exhibit No. 85 connected to a crystal detector circuit on the other hand the device would be receiving audio frequencies, would it not?

Answer. I assume that in both cases there would be what perhaps might be called audio-frequency modulation. In the first case, if the currents went through they would be, I assume, already in the form of mere ordinary telephone currents and I do not know just what would happen to them in such an apparatus as Exhibit No. 85 indicates.

65. Cross-question. What would be the form of the currents in the apparatus in the second illustration?

Answer. I assume that they would be in the form of radio-frequency pulsations.

66. Cross-question. In all of the bulbs?

Answer. Yes; so far as I have investigated the matter they go through them all.

67. Cross-question. If the pulsations in the last bulb are radio-frequency pulsations, how can any sound be heard in the receiving instrument?

Answer. It is what I have referred to as audio-frequency modulation that is heard, in the receiver R, in Exhibit No. 85.

68. Cross-question. Does what you call audio-frequency modulation in this case amount to anything more than saying that you have audio-frequency amplification and that it is the amplified audio frequencies that are heard in the receiving instrument?

Answer. If I understand the question, I would answer it yes. In other words, it is possible to put in place of [fol. 430] the receiver R a radio-frequency circuit tuned to the original radio frequency and through another detector system take off radio frequency from the last bulb C, and in fact to add further radio frequency amplification. In fact, the term "audio frequency" as used in this series of questions does not mean very much, except as designating the fact that signals can be heard when the receiver is connected either at R, R^1 or R^2, in Exhibit No. 85.

69. Cross-question. In your deposition in this case, have you used the term "audio frequency" in any sense other than meaning such frequency as will enable the signal to be heard?

Answer. No; I think not—I understand it to designate such a modulation of the direct current in the plate circuit as will permit the telephone to respond.

70. Cross-question. Now, under the assumption that the terminals of Exhibit No. 85 are connected to a crystal detector circuit, the incoming radio frequencies would be rectified into audio frequencies by the crystal detector, would they not?

Answer. No; they are rectified into a succession of radio-frequency pulses.

71. Cross-question. And these radio frequency pulses—would they be heard if passed through a telephone in the crystal detector circuit?

Answer. If the telephone has in shunt with it a sufficient capacity which can be charged and thereafter is discharged through the telephone, this discharge would be in the form of the so-called audio-frequency pulse due to the time constant of the telephone circuit.

72. Cross-question. And these audio-frequency pulses are then passed on to the grid filament circuit of the first bulb of Exhibit No. 85 and there amplified in the plate circuit of the first bulb of Exhibit No. 85, are they not?

Answer. Exhibit 85 does not indicate how the connection to the plate circuit is made, and I do not remember ever having seen any authoritative investigation as to just what happens, but I do know that radio frequency goes through the first tube and apparently is amplified. I understand that what probably happens is that the capacity of the transformer winding is probably sufficient so that there is in effect a combination of frequencies which passes through, the resulting output of the last tube being a direct current modulated at both radio and audio frequency rates.

73. Cross-question. Do you understand that the radio frequencies, which you say pass through all of the bulbs, are increased in power from one bulb to the next and so on to the last bulb?

Answer. Apparently they are.

74. Cross-question. Do you understand that there is in the art such a thing as a radio-frequency amplifier?

Answer. Yes; there are numerous forms.

75. Cross-question. All of them employ the three-element vacuum bulb, do they not?

Answer. In practice, so far as I know: yes.

76. Cross-question. What do you understand to be the difference between the radio-frequency amplifiers and the audio-frequency amplifiers?

Answer: The difference lies chiefly in the inductance of the transformer circuit. In a resistance coupled amplifier [fol. 431] there hardly seems to be any difference and the several functions of the tubes seem to be inextricably mixed. In the most popular type of present-day transformers the difference seems to be that radio-frequency transformers have a minimum impedance at about the radio frequency whereas the audio-frequency transformers have a minimum through some more or less broad range of audio frequencies.

77. Cross-question. May we take it as being your view that there is no essential difference in function or mode of operation between the radio-frequency amplifier and the audio-frequ ..cy amplifier?

Answer. The question is in such general terms that I would not know what any categorical answer to it would mean. My view is that either constitutes a useful part of a detector when the received energy of itself does not produce a sufficient response.

78. Cross-question. Do you understand that both of these devices embody what you understand to be the invention of the Fleming claims in suit?

Answer. Yes.

79. Cross-question. Do you understand that there would be any essential difference in function or mode of operation of the amplifier device if the audio frequencies were recei ed from a telephone circuit instead of from a radio-detector circuit?

Answer. I have already said I do not know what the device of Exhibit No. 85 would do if connected to an ordinary telephone circuit. I am familiar with the device connected to a radio-receiving circuit and that use in my opinion constitutes a part of the receiving detector.

80. Cross-question. Please consider that the amplifying device is of the type indicated in the sketch which I now show you, instead of that specifically shown in Exhibit No. 85, and say whether or not there would be any essential difference in function or mode of operation of the device if the audio frequencies are received from a telephone circuit instead of from a wireless-detector circuit?

Answer. I don't know in what sense of the word "type" is used in the question nor do I know anything about the bulbs, the transformers, or the battery values. I am personally familiar with the Forest audion amplifier, as shown in Exhibit No. 85, but I do not know anything about the type of apparatus shown in the blue print handed me.

Mr. Edwards. The sketch shown the witness is offered in evidence by defendant's counsel and marked "Defendant's Exhibit D."

81. Cross-question. Have you any difficulty in understanding that a device such as shown in this sketch would operate to amplify telephone currents if connected to a telephone circuit?

Answer. I assume that that depends on the design of the transformer and tubes, the proper selection of battery voltages, of course, I am familiar with the fact that tubes are used for amplifiers in telephone circuits but I have no personal information as to how they are used nor do I remember the circuits employed.

82. Cross-question. You have no difficulty in understanding that an amplifier of the kind shown in this sketch employing the three element bulbs as shown could be adjusted with suitable design of transformers, tubes, battery voltages, etc., and connected to a telephone circuit to amplify telephone currents, have you?

[fol. 432] Answer. Very likely, it might, I do not know whether it would or not. Of course, in such case there would be no radio frequency present and it would simply be a question of whether the arrangement is one that can handle voice currents, in a proper manner. I had not assumed that such an arrangement as the sketch shows was actually used, but I do know whether it can be used or not.

83. Cross-question. Do you not know that these three-element tubes are in every day use throughout the country in telephone circuits for the purpose of amplifying telephone currents?

Answer. As a matter of information, yes; but whether the diagram shown me is even schematically correct, I do not know and, as I say, I did not have the impression that that sketch showed what was used.

84. Cross-question. Do you not know that the use of these tubes in telephone circuits for amplification purposes far exceeds their use for wireless purposes at the present time?

Answer. I know that such tubes are used in telephone circuits and in very many other ways other than radio, but I have no information as to just how they are used in telephone circuits.

85. Cross-question. Do you not know that when the tubes are used in telephone circuits for amplifying telephone currents, they are connected up in circuits which are approximately the same as those schematically shown in this sketch Exhibit D?

Answer. I do not know—such information as I have would lead me to doubt it.

86. Cross-question. Wherein do you think the telephone circuits differ schematically from the circuit shown in this sketch?

Answer. I have not sufficient information in the matter to answer.

87. Cross-question. When these tubes are used in telephone circuits, do you understand that they embody what you understand to be the invention of the Fleming claims in suit?

Answer. I have no opinion to offer in the matter—I can only say that I have not assumed that they did.

88. Cross-question. What is your opinion on this subject?

Answer. I have no considered opinion to offer.

89. Cross-question. Do you understand that there is any essential difference in the function or mode of operation of the tube when connected in the telephone circuit from its function and mode of operation when connected in a wireless detector circuit?

Answer. When used in a wireless-telegraph combination, it handles frequencies of the order used in wireless communication—when used in telephone lines for commercial telephony, I assume that it does not.

90. Cross-question. What is the order of the frequencies used in wireless communication?

Answer. At the present time, I suppose that the range is approximately comprehended between 20,000 and a million and a half cycles per second.

91. Cross-question. And what is the order of the frequencies used in telephone lines?

Answer. I don't know.

92. Cross-question. Have you any idea?

Answer. I suppose it runs from sixteen to three or four thousand.

[fol. 433] 93. Cross-question. And what is the order of the frequencies which you have referred to in your testimony as audio frequency?

Answer. I assume that audio-frequency transformers are best adapted to handle about a thousand cycles of audio frequency. That is, I assume that the minimum impedance is at about that frequency.

94. Cross-question. Does that mean that the order of the frequencies referred to in your testimony, as audio frequencies, is about 1,000 cycles per second?

Answer. I have in the main had the term put in my mouth by counsel. I have assumed that 1,000 cycles might be taken as illustrative of what he meant and so far as I

remember my answers are in accordance with that understanding.

95. Cross-question. When Mr. Clark, whose testimony descriptive of the apparatus concerning which you testified in your direct examination you referred to, used the term "audio frequency" with reference to this apparatus, what order of frequency do you think he was referring to?

Answer. A frequency which would distinctly actuate the receiving telephones, I assume, it being the purpose of the detector only to produce such a result. I suppose 1,000 cycles would be a correct assumption.

96. Cross-question. Do you think that there is any difference in function or mode of operation of these vacuum tubes when operated by the current at 20,000 cycles, from what it is when operated by currents at 1,000 cycles?

Answer. Speaking broadly, that is in the most fundamental sense, no—but, of course, everyone who is practically familiar with what is known as high-frequency currents knows that the phenomena attending the use of high-frequency currents are very different and that properties of the circuit and the apparatus which do not manifest themselves at all at low frequencies, become of extreme importance in high frequencies; therefore, the general statement that the mode of operation is the same may easily be misleading.

97. Cross-question. Have you made inquiry of the Marconi company to ascertain if you can get some two-element bulbs, similar to those which you claim were demonstrated before Judge Mayer?

Answer. No; I have not; I am sorry to say that I forgot it.

98. Cross-question. Will you report the result of your request to the commissioner as soon as you can?

Answer. Yes; I will.

Mr. Peters. I offer in evidence pamphlet entitled "Elemental Principles of Radio Telegraphy and Telephony," prepared in the office of the Chief Signal Officer, 1921 (Washington, Government Printing Office, 1922), Radio Communication No. 1, marked "Plaintiff's Exhibit No. 119."

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The examination by counsel being concluded, the witness, in compliance with the rule of the court requiring him to

state whether he knows of any other matter relative to the claim in question, and if he does to state it, says he does not. [fol. 434] In compliance with the request of cross-question 98, I report to the commissioner as follows:

I have made careful inquiry as to the possibility of obtaining one of the two-element bulbs used in the demonstration made before Judge Mayer of the oscillating capacity of the bulbs of the Fleming patent or in lieu thereof to obtain one from the same original lot of tubes or one of similar construction. Up to now, however, I have been unsuccessful in ascertaining whether or not there are any still in existence. It is possible, I understand, to reproduce them should the United States Government desire, if sufficient time is allowed to ascertain their dimensions from old records and to obtain the necessary materials.

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[fol. 435] Stipulation—Filed December 3, 1924

It is stipulated, by and between the attorneys for the respective parties, that the annexed is a true copy of the testimony given by Guglielmo Marconi on the 17th, 18th, and 25th of June 1913, in the suits brought by Marconi Wireless Telegraph Company of America, plaintiff, *vs.* National Electric Signaling Company, defendant, in equity No. 23 on reissue patent No. 11913 and patent No. 609154, and Equity No. 31, on patent No. 763,772 both in the United States District Court for the Eastern District of New York and that said Guglielmo Marconi, if called as a witness in this case and duly sworn, would repeat said testimony, and that said testimony may be read into and made a part of the record in this case and used with as full force and effect as if taken herein.

It is further stipulated that copies of the exhibits offered in evidence on behalf of the plaintiff in connection with the said testimony, marked 14 A, Marconi Sketch No. 1; 14 B, Marconi Sketch No. 2; 15, Copy of L'Elettricista of Aug. 1, 1897; 16, Article in Times London, Sept. 23, 1896; 17, Clipping from Daily Chronicle on Dec. 14, 1896; 18, Article in Electrical Engineer of London, Dec. 18, 1896; 19, London Engineer, June 18, 1897; 20, A, Bristol Channel Tapes; 20 B, Bristol Channel Tapes; 21 A, Article by Prof. Slaby, dated April, 1897; 21 B, Translation of Article by Prof. Slaby, dated Berlin April 1897; 22, Rivista Marittima;

23, Proceedings of Naval Institute; 24, Marconi Patent No. 884,986; 25, Marconi Original Note Book; 26, Marconi Royal Institute Lecture; 27, Publication of Prof. Banti of 1897; 30, Letter of the Minister of Marine; 31, Marconi No. 10,245, of 1902 (British); 32, Brazilian Patent, August, 1902; 33, Electrician of Jan. 20, 1902 (p. 346); 34, Electrician of July 18, 1912 (p. 520); 35, Electrical World and Engineer, N. Y., of July 12, 1902; 36, La Telegraphie Sans Fil, by M. E. Ducretet; 38, Partial Translation of Ducretet Pamphlet, Defendant's Exhibit No. 70; 41, No. 30,506, of Nov. 3, 1900 (French); 42, Clipping of Daily News of St. John Newfoundland; 43, Clipping of Evening Herald; 44, Extract from Minutes of St. John's Municipal Council Meeting; 45, Original Philadelphia Tapes; 46, Original Philadelphia Charts; 47, Report of Admiral in Command of Carlo Alberto; 49, Electrical World and Engineer of January 18, 1902, may be marked in evidence herein by the plaintiff as Plaintiff's Exhibits 117 to 149 inclusive, and that said copies may be used with the same force and effect as the original exhibits.

Dated New York, January 19, 1924.

L. F. H. Betts, Attorney for Claimant. Clifton V. Edwards, Special Assistant to the Attorney General. Robert H. Lovett, Assistant Attorney General of the United States.

[fol. 436] United States District Court, Eastern District of New York

Before Hon. Van Vechten Veeder, *J.*

D. E. No. 23. In Equity. On U. S. Patents. Re-Issue No. 11913, and 609154

Marconi Wireless Telegraph Company of America, Complainant,

versus

National Electric Signaling Company, Defendant

U. S. Post Office Building, Borough of Brooklyn, City of New York, Tuesday, June 17th, 1913

The Court met pursuant to adjournment at 10:30 o'clock A. M.

Present:

Parties as before.

The Court: Proceed, gentlemen.
Mr. Betts: Mr. Marconi, will you take the stand?

Guglielmo Marconi was called as a witness by and on behalf of the complainant, and having been first duly sworn, testified as follows:

Direct examination.

By Mr. Betts:

Q. Will you please state your name, residence, and occupation?
A. Age, 38 years; residence, Italy—I might say Italy and England; occupation, electrical engineer.
Q. Where were you born?
A. I was born in Italy, in the Town of Bologna.
Q. Where were you educated?
A. I was educated in Italy.
Q. At what institution of learning?
A. At various primary and secondary schools, and I also attended some lectures at Bologna University.

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[fols. 437-438] Q. Are you the G. Marconi to whom was granted reissued letters patent of the United States No. 11913?
A. I am.
Q. Will you please state what you did, if anything, towards putting into successful use the invention of this patent, prior to the time that you filed your application?
A. I might say that from a boy I was always interested in physics and in electric phenomena generally, and I think in the summer of 1894 I read of the experiments and results of Hertz in Germany. I also was acquainted with the works of Lord Kelvin, and with the theoretical doctrines of Clerk Maxwell. I experimented with electrical waves, as I considered that line of research very interesting, and during these tests or experiments I thought that these waves, if produced in a somewhat different manner from the way that had been produced by Hertz, that is,

if they could be made more powerful, and if receivers could be made more reliable, they would be applicable for telegraphing across space to great distances.

* * * * * * *

[fol. 439] Q. How far did you actually succeed in transmitting intelligible messages, using the exact connections shown in your patent No. 11913, that is with the spark gap and the detector directly connected between the earth and the antenna?

A. About thirty or forty miles. I think it was forty.

Q. When first, if ever, did you actually try to send a message from a transmitting station in which the spark gap was inductively connected to the antenna and the ground?

A. In 1898, 1899. About the end of 1898.

Q. When first, if ever, did you try to send any messages in which the receiving apparatus was arranged with the coherer or detector inductively connected between the antenna and the ground?

A. 1897 or 1898. The beginning of 1898; the end of 1897, if I remember correctly.

[fol. 440] XQ. Is not Professor Fleming connected with your company—the complainant company?

A. Yes.

* * * * * * *

[fol. 441] Q. I believe that you have already testified as to what you did toward putting into successful operation your wireless telegraph apparatus up to the year 1900. I show you a copy of United States Letters Patent to G. Marconi, No. 763,772, being the patent in suit, and ask if you are the Marconi to whom was granted these letters patent?

A. Yes.

Q. Have you obtained any patents in any other countries foreign to the United States for the invention corresponding to your patent No. 763,772 of the United States?

A. Yes, in many other countries. I might mention, particularly, in England and in France.

Q. Can you produce a certified copy of the British patent, and also a certified copy of the French patent?

A. Yes, I can produce certified copies of both the British and the French patents to which you referred.

Mr. Betts: I offer in evidence certified copy of British Marconi patent No. 7,777, of 1900, and ask that it be marked

Complainant's Exhibit No. 40. Also, certified copy of French patent No. 30,506, to G. Marconi, dated November 3, 1900, and ask that it be marked Complainant's Exhibit No. 41.

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(The papers so offered and identified were thereupon marked, respectively, "Complainant's Exhibit No. 40" and "Complainant's Exhibit No. 41" of this date.)

* * * * * * *

[fol. 442] By Mr. Betts:

Q. Has the invention of your United States patent No. 763,772 been put into use by you or by the companies owning the patents for your wireless telegraph inventions?

A. Yes, it has been put into use. I should say, put to very great use.

Q. How great a distance were you able to actually transmit and receive intelligible messages prior to the adoption and utilization of the invention of your patent No. 763,772?

A. About eighty miles. I think eighty-three miles is the exact distance.

Q. You have stated that the invention of your patent No. 763,772 has been put into large and successful use. How great a distance have you successfully transmitted messages, due to the utilization of the invention of your patent No. 763772?

A. 6,600 miles.

* * * * * * *

Q. When first was the invention of your patent in suit, No. 763,772, put into commercial use by you, and where?

A. In the year 1900, in England.

Q. Whereabouts?

A. It was first installed at stations on the Isle of Wight, and on the coast of England, and afterward, at other stations, all around the coast of the United Kingdom, and on ships.

Q. And when first was the invention of your patent No. 763,772 in suit, used outside of England by you or by your company?

A. It was used—I remember a definite case—on the Nantucket Lightship in the United States of America, in

August, 1901. At least, it commenced to be used that month, and it has been used, I think, ever since.

Q. And after August, 1901, when did you utilize this invention for long distance transmission?

A. It was utilized in the tests of transatlantic transmission, which took place in the autumn of 1901, between [fol. 443] Poldhu and Newfoundland. It was also utilized in a number of other test tubes, which, perhaps, I need not refer to.

Q. When did you first succeed in transmitting an intelligible Morse letter or word across the Atlantic? A. December, 1901.

Q. Did you use the invention of this patent during that test?

A. Yes, I did.

Q. Can you produce any evidence corroborating or tending to corroborate you in the statement that you transmitted an intelligible signal across the Atlantic in December, 1901?

* * * * * * *

A. I produce a copy of the *Daily News*, of St. John, Newfoundland, of 16th of December, 1901, and also a copy of the *Evening Herald*, December 16, 1901, which describe, I think, what I did in Newfoundland. I also produce an official extract from the minutes of a meeting of the St. Johns Municipal Council, held on Friday, December 20, 1901, which states:

"On Thursday, 12th of December, at 12:30 P. M., Signor G. Marconi, with his wireless telegraphic receiving apparatus, stationed at Signal Hill, and by means of an aerial wire supported by a kite, received signals sent by a prearrangement from his transmitting station at Poldhu, Cornwall.

"On Monday evening, 16th of December, the Anglo-American Telegraph Company, having learned of Signor Marconi's success, served a notice of their monopoly rights upon him, and threatened legal proceedings in the event of his not stopping operations at once.

"The Council are much gratified at Signor Marconi's success, marking, as it does, the dawn of a new era in Trans-Oceanic telegraphing, and deplore the action of the Anglo-American Telegraph Company.

"It was further ordered that the above minutes be engrossed and transmitted to Signor Marconi.

(Signed) H. C. Burchell, Chairman."

Mr. Betts: I offer these in evidence, and ask that they be marked, respectively, Complainant's Exhibits No. 42, 43 and 44.

[fol. 444] (The papers so offered and identified were thereupon marked, respectively, "Complainant's Exhibit No. 42," "Complainant's Exhibit No. 43," and "Complainant's Exhibit No. 44," of this date.)

By Mr. Betts:

Q. Were you yourself at St. John's in December, 1901?
A. Yes, I was.
Q. When did you return to England?
A. I returned to England some time in January, 1902.
Q. On what boat?
A. I think it was the "*Philadelphia*," of the American Line.
Q. Did you conduct any tests while on the "*Philadelphia*"?
A. Not on that trip. On my return from England to the United States, a few weeks afterward, I conducted some tests.
Q. And the tests were with what station?
A. The tests were with a station at Poldhu, in Cornwall.
Q. And the station at Poldhu, in Cornwall, was that equipped with the invention of your patent in suit?
A. It was equipped with the invention of my patent in suit.
Q. Now, when you were on the *Philadelphia*, coming from England, how great a distance from Poldhu did you actually receive telegraphic Morse signals or messages?
A. I received them up to a distance of 2,099 miles. These messages were not simply received on a telephone. They were received on tape. They were recorded signals, and in nearly all the tests a printing instrument, actuated by a coherer receiver, was employed. As those tests were of considerable importance, both from a technical as well as from an historical point of view, I got the captain and the chief officer of the ship to prepare a chart, duly signed by them, showing the positions at which messages and signals

had been received from England, and also to countersign the tapes received on the Morse apparatus, which showed messages or signals, which messages or signals were received on those tapes in the presence of the officers who signed the tapes.

Q. Look at the two cardboards which I hand you and state, if you know, what they are.

A. The first cardboard represents messages, the actual tapes received at varying distances, and signed by the captain of the *Philadelphia*, and I think, in certain cases, by the chief officer as well. They represent messages and signals received at distances from one thousand and thirty-two miles up to two thousand and ninety-nine miles. I should say, to the second cardboard is attached the original chart, to which I have referred in my previous answer, which shows the positions where messages and signals were received. This chart was prepared and signed by the captain of the *Philadelphia* and by the chief officer, and their signatures appear on the chart.

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[fol. 445] Mr. Betts: I offer in evidence the two charts, or at least the two cardboards, identified by the witness, the first being the cardboard containing the original *Philadelphia* tapes, and ask that it be marked "Complainant's Exhibit No. 45"; also, the second cardboard, being the chart of the *Philadelphia*, and I ask that that be marked "Complainant's Exhibit No. 46."

• • • • • • •

By Mr. Betts:

Q. Were you on the *Philadelphia* yourself when these messages were received which are indicated on the *Philadelphia* tapes?

A. Yes, I was.

Q. Did you actually receive any of these messages?

A. All of them.

(The cardboards so offered and identified were thereupon marked, respectively, "Complainant's Exhibit No. 45" and "Complainant's Exhibit No. 46," of this date.)

By Mr. Betts:

Q. What kind of a detector did you use in December, 1901, when receiving the signals from Poldhu?

A. I used the ordinary coherer, which has been referred to in the previous case; and I also used another form of coherer, which did not require tapping, and by means of which the signals were received telephonically instead of by means of the Morse instrument.

Q. And what kind of detector did you use on the *Philadelphia* in these tests for which you have produced the original tapes?

A. I used the original coherer, as described in the patents that we have been discussing here, in the previous case.

Q. Now, what next did you do in 1902 toward demonstrating the successful use of the invention of your patent in suit?

A. On my return to England, in the Spring of 1902, I was invited by the Italian government to carry out tests between this station established at Poldhu, and a war ship of the Italian Navy. Receiving apparatus and also transmitting apparatus was installed on the war ship, and, I think, commencing about the 18th of June, tests were made between England and this war ship in various parts of Europe. Thus signals were obtained between Poldhu and Kronstadt, in Russia, fifteen hundred miles, I believe. Also, when this ship was at Kiel, in Germany, and at other places in Germany; also, at Gibraltar, to the south of England, the distance between the two places being one thousand miles, and the waves having to travel over the whole of Spain and the mountains which divide Spain from France, and then, later on, communications were successfully established between Poldhu and this ship in the Mediterranean—at various points in the Mediterranean, the great point of interest [fol. 446] being then that these waves traveled across the whole of France and across the Alps, which happened to be in a line between the transmitting and receiving instruments. The tests were considered very interesting and important at the time, and an official report was prepared by the Admiral in command of the squadron to which this cruiser "*Carlo Alberto*" belonged, and which report I produce. I should add that the report shows the arrangement of the aerials, sets forth the various places where messages

were received, and also gives a reproduction of the tapes received by means of the recording instrument at various places, showing the messages which were actually recorded at those places, and over given distances.

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Mr. Betts: I offer the report in evidence, and ask that it be marked "Complainant's Exhibit No. 47,"

(The paper so offered and identified, was thereupon marked "Complainant's Exhibit No. 47," of this date.)

By Mr. Betts:

Q. What kind of a detector did you use on the *Carlo Alberto* during these tests at Kronstadt, in the Mediterranean, and at Kiel?

A. The signals shown on the tapes reproduced in the report were obtained by means of what I might call an ordinary coherer receiver, but during those tests a magnetic receiver was also used, and also a telephone or an imperfect electrical contact.

Q. What kind of transmitting and receiving apparatus was the *Carlo Alberto* equipped with?

A. It was equipped with transmitting and receiving apparatus according to the invention described in Patent No. 763,772.

Q. Was the invention of your patent in suit ever put into use by the complainant company after the Nantucket Lightship installation? If so, when first for long distance work?

A. It was put into operation at the long distance station at Cape Cod, and very shortly afterwards, at the station which was erected, partially at the expense of the Canadian Government, at Cape Breton, in Canada.

Q. Did you ever conduct any tests for the British Admiralty with apparatus involving or utilizing the invention of the patent in suit?

A. Yes, tests were carried out for the British Navy, [fol. 447] about the end of 1900, and shortly afterwards, it was adopted on all the ships of the navy which were using wireless, and, I think, now its use is general on every ship in the British Navy.

Q. What commercial use is made of the invention of the patent in suit by you or your companies owning corresponding patents—Marconi patents?

A. It is used at four or five long distance stations; I mean, stations having a range of two thousand miles or so. It is used at about twenty shorter distance stations—stations having a range of eight hundred to a thousand miles; and it is also used at about a thousand shore-and-ship stations, which conduct business over what I should call a short distance—anything from two hundred to five hundred miles.

Q. Have you ever used a transmitter where the spark gap was in inductive relation to the antenna, but such a spark gap circuit was not tuned to the antenna circuit?

A. Yes, I have.

Q. Where and when?

A. In England, I think in 1899 or some time about that.

Q. With what success did you meet in using such a transmitting apparatus?

A. I met with no success. I found that it was no good, compared to what I had been originally using.

Q. Referring now to your patent No. 763,772, you have illustrated and described on pages 3 and 4 certain apparatus. Did you ever build and use any of the apparatus therein illustrated and described, and if so, when first?

A. I use the apparatus described in the patent to which you have referred in the Spring of 1900—I think in March or April of that year.

Q. Was that before or after you had filed your application for your British patent No. 7,777?

A. That was before.

Q. The defendant contends in this case that the two circuits at the transmitting station, shown in your patent No. 763,772, are tightly coupled, or closely coupled. What have you to say as to this?

A. I have to say that they are not. Of course, I have got to interpret the term "closely coupled," or "tightly coupled," as what is meant in regard to these circuits,

Q. What is the degree, approximately, of coupling of the transmitting circuits using the apparatus as illustrated and described in the specification of your patent in suit?

A. I have not got the figures before me, but I think that the first four or five tunes are loosely coupled; that is, of an order of ten per cent, or perhaps under. The tune [fol. 448] No. 6 is also loosely coupled, but probably of a degree of coupling of over ten per cent. I think I remember Prof. Fessenden stating somewhere that he considered any-

thing under fifty per cent loosely coupled, and anything over fifty per cent was tightly coupled. Therefore, according to his definition, with which I, to a certain extent, agree, I should say these are all loosely coupled.

Q. Even if it be true that an oscillation transformer be tightly coupled, if such a transformer is connected into an antenna or open circuit of a wireless telegraph station, the antenna being, say one hundred feet high, what effect, if any, does this have on the degree of coupling of the two circuits?

A. The coupling depends entirely on the linking or coupling of the two circuits, the closed osciliating circuit and the radiating circuit or the receiving circuit which includes an aerial—the whole of the aerial and every other connection. That circuit may include an oscillation transformer, which may be itself tightly coupled, but it does not necessarily make the whole circuit tightly coupled, because that coil is only a very small part of the circuit, and only a small part of the magnetic lines of force are common to the two circuits. One might have a coil, or rather, I should say, a transformer, connected to earth and to a radiating wire, which would be tightly coupled to its other circuit, if the radiating wire were only a foot or two long; but if the radiating wire were a hundred feet long or a thousand feet long, or as it is in some aerials now, about ten thousand feet long, it would hardly be coupled at all. Any such circuit which may include an oscillation transformer, would be coupled very weakly indeed. Therefore, in considering the coupling between two circuits such as are described in this patent and such as we are discussing now, it is absolutely absurd to take only the transformer part of the circuit and say that the whole circuit is tightly or loosely coupled.

Q. The defendant contends that a coherer circuit cannot be tuned. What have you to say as to that?

A. I do not agree with him.

Q. How do you tune a coherer circuit?

A. We tune it by proportioning the inductance and the capacity of the circuit in which it is, so that that circuit will be in tune w-th the oscillations which you want to receive. The exact proportion of the inductance of the circuit, of course depends, in certain cases, on whether you are using a high resistance coherer or a low resistance coherer.

Q. Now, please look at your patent No. 627,650, which is

Defendant's Exhibit No. 61. I understand that there is a condenser shown in that patent. Is that true?

A. Yes. There is a condenser shown in figure 1.

Q. What was the purpose for which you put that condenser in the circuit shown in Figure 1 of your patent—of Defendant's Exhibit No. 61?

A. The purpose of a condenser K-1, shown in Figure 1, is to prevent the short-circuiting of the battery through the coil J^2, and at the same time, to enable the high frequency oscillations from the coil J^2 to reach the terminal of the coherer T.

Q. What was the purpose of using the transformer shown in Figure 1 of Defendant's Exhibit No. 61?

A. The purpose of using the transformer was to increase the potential of the oscillation at the terminals of the tube T, and therefore, make it act at a greater distance.

[fol. 449] Q. Suppose that a condenser is shown or described as being utilized in the secondary of two oscillating circuits, without any mention being made as to the purpose of utilizing such a condenser. What have you to say as to whether or not those two circuits are or will be in tune with one another?

* * * * * * *

I would assume they were not in tune.

Mr. Betts: I should like to offer in evidence, at this point, a certified copy of the decision of Judge Parker in the suit of Marconi's Wireless Telegraph Company against the Radio Company, upon British patent No. 7,777, of 1900. I ask that Judge Parker's decision be marked "Complainant's Exhibit No. 48."

The Court: You may mark it for identification. I will reserve decision on it.

(The paper referred to, was thereupon marked "Complainant's Exhibit No. 48, for Identification," of this date.)

* * * * * * *

[fol. 450] By Mr. Betts:

Q. Referring to pages 3 and 4 of the patent in suit, in which you give details of the construction of the transformer, induction coils, and so forth, where did you get the information contained in this part of the specification of the patent?

A. I got it from actual tests carried out at one of my stations in England—rather, at two of my stations in England. I want to add something to that, if I may.

[fol. 451] Q. Yes.

A. And the details and dimensions are taken from actual apparatus, which was used for the purposes described.

Q. Dr. Kennelly, the defendant's expert, on page 467 of the defendant's record, says:

> When the associate circuits are so closely interlinked as those the sending station of the Marconi plant in suit, and particularly when they are as closely interlinked as those at the receiving station, the statement is incorrect.

A. To what statement does that refer?

Q. This statement of Dr. Kennelly's was made with reference to the following question. "The Marconi patent in suit states, in effect, that the product of capacity and inductance of the four circuits must be equal?" Do you agree with Dr. Kennelly's statement that the oscillating circuits at the receiving stations and the sending station are so closely interlinked that the product of capacity and inductance of the four circuits is not equal?

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A. I am just looking at this, your Honor. I do not agree with Dr. Kennelly's statement, and I also do not agree with his opinion that the circuits in the patent in suit are tightly coupled.

Q. By "circuits", do you mean those only at the transmitting station, or do you include the receiving station as well?

A. I include both.

Mr. Betts: That is all.

Cross-examination.

By Mr. Clay:

Q. On the following page Dr. Kennelly says that the principles he is referring to were demonstrated in an article by Houston himself, dated July 10, 1897, in the *Electrical World?*

A. What page is that?

Q. 468, which refers to one of the defendant's exhibits, No. 86, on the theory of electrical oscillations in mutually inductive circuits; and he does you the credit to say that he does not consider the inaccuracy of your statement in your patent would prevent the direction of the patent from being executed, because in practice, the tuning would be effected experimentally by trial and not by computation. That is true, is it not?

A. No, I do not think so.

Q. Do you think that in the practice of wireless telegraphy the tuning of the circuit is made by calculation and not by trial?

A. Yes, sir. In most cases it is made by measurement.

Q. In your experiments at Newfoundland, you had a kite, didn't you?

A. Yes, sir.

Q. And I do not suppose the kite remained still?

A. It did sometimes.

Q. Didn't it move up and down?

A. Not enough to vary it much.

Q. Didn't that change the tuning of the antenna?

A. Varies its movement slightly.

[fol. 452] Q. You do not intend to have the Court understand that an antenna which is held by a kite at an unknown elevation can be calculated as to its tune?

A. It does not vary much.

Q. You could not calculate beforehand even how high the kite was going, could you?

A. No, sir; but I could know what—I would know how to tune a local circuit to that wire when the kite was at a certain given height: if it varied its height it would not receive.

Q. You couldn't know beforehand the electrical tuning of the antenna?

A. Yes, sir, I could.

Q. By using a kite?

A. If it was at a certain angle and the wire at a certain length.

Q. How do you know what the wire is going to be?

A. You measure it.

Q. You measure it as the kite goes up?

A. Certainly.

Q. Does the height above the earth make any difference?

A. Certainly.

Q. Would not the height vary without changing the wire.

A. Yes, sir. You can measure that by the angle.

Q. Which angle?

A. From the position of the kite. If it is vertical you know it is at the height equal to the length of the wire, but when the kite is not vertical then it is at another height, which you can calculate from the angle. I should add that balloons were also used in Newfoundland, not always kites.

Q. In that case there were wires in the form of a catenary, and its length depends upon the tension? A. Its length depends on hiw long it is.
depends on how long it is.

Q. The height of the antenna depends on the tension, the angle, or the wind force?

A. I don't understand.

Q. Don't you, as a matter of fact, tune the local circuit of the antenna instead of trying to figure what the period of the antenna is beforehand?

A. No, sir. I do not do that exactly.

Q. In that case didn't you?

A. No, sir. I knew the length of the wave radiated from Poldhu, then I had to let out sufficient wire, which I knew would be tuned to that length of wave and then I had to tune my local circuit to that length of wire and to the wave radiated.

Q. Did you take the trouble to read Dr. Kenneily's article in which he gives the laws of such tuning?

A. No, sir; I did not.

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Q. When he spoke about your inaccuracies, isn't it strange that you did not take the trouble to look up his article which he says gives you the laws of this tuning?

A. Well, I think I have said I have not read his testimony; therefore, I did not see his statement.

Q. Do you undertake to answer his statement without reading either the whole of the statement——

A. I am not answering any of his questions. I am an-
[fol. 453] swering your questions. I haven't said whether he is right or wrong. I think he is wrong, but I would like to see his article.

Q. I thought Mr. Betts asked you whether he stated it correctly?

A. As to 467. That is all I know.

Q. Taking this figure of this chart, take the complainant's illustrative chart and take the sending station of your patent in suit, you were speaking of the linkage or coupling there and, as I remember it, you said that the linkage did not depend on the mere inductance of those two coils dd', but partly on the rest of the antenna, is that true?

A. No. I should say that it does not depend on the two coils dd'. It is not a question of inductance, it is a question of how close they may be together.

By Mr. Clay:

Q. You could have a coupling that was a loose coupling in one direction and not in the other?

A. I don't understand what you mean.

Q. What has the length of the antenna to do with it?

A. We are talking of the coupling of the two circuits?

Q. The coupling of the two circuits depends on the linkage?

A. Of the two circuits?

Q. Between the coils d and d', doesn't it?

A. No, sir, not at all.

Q. They certainly do not depend on anything that is occurring anywhere else in the antenna?

A. I absolutely disagree with you, and you put your question in such a way that it is scientifically absurd, with all due respect.

Q. That may be. I do not claim to be a scientist. But my understanding was that the coupling— Let me say. If all the magnetic lines of the two upon the magnetic lines and forces that were common to the two circuits, isn't that true?

A. Yes. Let me say. If all the magnetic lines of the two circuits are common to each other, then the coupling is perfect, it is 100 per cent; but if a great number of the magnetic lines are not common to the two circuits then the coupling is only a part of a unit. It is only a fraction of complete coupling, therefore, it is obvious to me if there are a great number of lines running away from that wire and from the other connections, as you have stated quite correctly, in that case the coupling cannot be strong because a great number of those lines are independent of the two circuits.

Q. In my opening argument, I used this sketch, which I think I will put on a little corner of the chart to make it convenient. I have stated to the Court that that was [fol. 454] an open and closed circuit linked or coupled together, is that true?

* * * * * * *

A. This shows an inductance shunted by a condenser which may be taken to represent a closed circuit, attached to the ends of the inductance, or two straight wires which we may take to represent an open circuit. I agree to that.

By Mr. Clay:

Q. It is an open circuit and a closed circuit linked together, or inductively connected together, is it not?

A. It shows an inductance shunted by a condenser which may be taken to represent a closed circuit attached to the ends of the inductance, or two straight wires which we may take to represent an open circuit. I agree to that.

Q. Don't you agree that it is an inductive coupling of the two circuits?

A. An inductive coupling?

Q. Yes.

A. Yes. I take it as an inductive coupling.

Q. Do you call it a loose coupling or a tight coupling?

A. I really don't know. I don't quite understand how these two circuits are coupled.

Q. If the antenna were elongated and become the kite that you used in your Trans-Atlantic test, would the antenna circuit and the local circuit be loosely coupled or tightly coupled?

A. I would have to think over that part for a little.

Q. You say in your patent in suit, and indeed I think in some of the claims, that the local circuit there in red ed and the antenna circuit a d'; earth, may be tuned to each other or to octaves. Do you think now that is true?

A. I think that is true in certain cases. Instead of the fundamental oscillation taking place in the antenna, the antenna may be oscillating to an octave or to a higher harmonic. In that case you can tune the circuit d e, to the octave. That has been done sometimes, but it is not the best way of utilizing the invention. I do not think it has been put in the claim.

[fol. 455] Q. Well, I stated to the Court in my opening argument that an electrical oscillation in this sketch of mine, between the aerial and the earth, passing through the coil, which is common to the two circuits, and inducting into the condenser circuit an induced current, would of necessity produce a current in the local circuit which is timed to that in the antenna. Is there anything wrong with that statement?

A. Yes, sir; I think it is wrong.

Q. What is wrong with it?

A. If an oscillation is produced there I think it will be a forced oscillation, and I really think the only effect of that condenser there will be to possibly decrease the period of the whole arrangement and possibly to make a larger current go through the inductance coil. I do not think you can take them as two circuits that can be turned together.

Q. You evidently recognize that as one of the references, don't you?

A. Yes, sir. I have seen it.

Q. When did you first telegraph across the ocean with the apparatus shown on the upper right hand side of that Chart 36-A, built as there shown?

A. The first intelligible signals were transmitted by the arrangement there shown in December, 1901, and actual messages, lengthy messages were transmitted in February, 1902.

Q. Now, in your figures in your patent for every one of those stations you give a length of aerial, and in this patent that means vertical height from the top of it to the ground, doesn't it or does it?

A. Where it is stated to be vertical I suppose it means vertical. I will have to read that.

Q. It does not say. It says at the top of page 4, 36.576 meters of cable is the aerial conductor?

A. I think it is described somewhere. It is vertical.

Q. Does that include the length of that coil as shown in the figure?

A. It does not unless the coil is described as being included, then the number of turns of the coil are given.

Q. Now, this Trans-Atlantic station could not have had any definite known length, height predetermined, put down like these figures are, could it?

A. I don't see why not.

Q. And you said in that Trans-Atlantic station experiment in 1901, when the antenna was a kite, you used magnetic and other imperfect contact receivers. Did you intend to intimate that the magnet was an imperfect contact receiver like the one disclosed in the patent?

A. I have already testified before that I am uncertain as to whether it can be classified as an imperfect contact.

* * * * * * *

[fol. 456] Q. The question now is that when you were testifying a short while ago you meant to intimate that it was an imperfect contact, didn't you?

A. I said that it can be considered to act in the same way. It opposes a variable resistance to the current that is going through it.

Q. When all of these messages were received, as illustrated on the exhibit charts and described in the exhibit newspaper articles, the persons responsible for the chart and the articles got that information from you, didn't they, that there were messages received and that they came from a certain place?

A. In many cases both the stations were watched, the transmitting end and the receiving stations.

Q. You did not answer my question. The persons who were responsible for those reports, newspaper articles and charts got their information as to the receipt of the signals and as to where they came from from you?

A. No, sir.

Q. Who did they get it from?

A. They got it themselves, by watching the tests in most cases; by seeing the messages come in and by receiving such news in mid-Atlantic or inaccessible parts of Newfoundland which they afterwards found to be accurate news, from England, and other parts of the civilized world at that time.

Q. They didn't know where they came from?

A. They certainly did know.

Q. How?

A. By the signals received and by the characteristics of the signals. A great number of people that were concerned with the messages, especially on the warships, were experts and knew perfectly well what the signals looked like and how they sounded and what they tuned to.

Q. Are any of those officers here as experts?

A. On the *Carlo Alberto* they were.

Q. Operators?

A. Experts; better than operators.

Q. How did they know they came from Poldhu, rather than across the street?

A. The same way as I could know, through expert knowledge. I mean they knew that Poldhu would be sending at a certain time with a certain wave length and in a certain manner. Those things had been arranged before. When they went to the instrument to see whether messages had been received or not they would perfectly well know it.

Q. Didn't you point out on one of these taps a dot which you said might have been made by an atmospheric disturbance or from a spark?

A. Not on one of these taps. You are speaking of long distance taps.

Q. I say a tap you had this morning?

A. That is a three-mile tap.

Q. My statement is true, is it not?

A. Any dot may be made by an atmospheric condition, yes.

Q. In that first Transatlantic signal your dot—your first Transatlantic sending of your signals were composed entirely of dots, weren't they?

A. Not entirely. There were dashes too. The first [fol. 457] letters were dots, were s's, but some letters including a dash were sent too, but I am quote ready to admit those which were sent, these long successions of s's, consisted of a repetition of dots.

Q. That is like this? (indicating by tapping a pencil three times on the railing)?

A. Yes, sir.

Q. Three ticks on the ticker separated by longer intervals between the s's, separating the clicks?

A. Yes, sir.

Q. That was all?

A. Yes, sir.

Q. You depend on the spacing to tell an atmospheric disturbance?

A. On the spacing, on the rhythm and on the way they were sent and at the time they were sent.

Q. An intelligible message with a series of clicks arranged in a certain predetermined order?

A. What is that?

Q. An intelligible message was a series of clicks arranged in a certain predetermined order?

A. Yes, sir; and I must add, at a certain prearranged speed and at a certain prearranged time.

Q. Yes. That is what I meant by order. I think, Mr. Marconi, you testified that Fessenden or Kennelly, or whoever it was said that you had a tight coupling was wrong, because they had considered only the lines of force concerned with the linkage of the two coils D and D′ in your transmitting station, isn't that about what it was?

A. Yes. I think they were wrong and I gave that as a reason. I am not sure that it was that reason, but I thought that they had overlooked the fact that they had to consider the whole circuit and not only part of the circuit in deciding whether it was loosely or tightly coupled.

Q. Can you make it clear to the Court how any part of the radiating circuit, say above the point I have marked in pencil, has anything to do with the coupling?

A. It certainly has everything to do with the coupling because it is part of the circuit, and it is part of the circuit which is not coupled.

Q. But it is not a part that is linked with the local circuit?

A. What?

Q. It is not a part which is linked with the local circuit?

A. No, sir; but it is a part of the circuit, and it is the only part of that which is linked to the other circuit. You must take the whole circuit from A to the earth, as a whole. There is only a very small length or part of this circuit which is linked to that. That is why that circuit is loosely coupled. If it was all coiled up in a coil around this circuit and none of it sticking up, or a few inches sticking up, then it would be very tightly coupled. That was my understanding of it.

Q. You say you have not read the defendant's testimony in this case?

A. I have read some of it. I haven't read it all.

Q. What part?

A. I have read only a very little of Fessenden's, and I haven't read Kennelly's at all.

Q. You are not undertaking to question their testimony about what is a loose coupling and what is a tight coupling?

A. I will undertake to answer the question to the best of my ability, but I cannot refer to a statement of others which I am not acquainted with.

Q. Don't you recognize Dr. Kennelly as an authority on the subject?

A. I think he is known in electrical engineering in America. And I have got no reason to say he is not an authority on those matters. I don't know if he has studied this particular subject as deeply as others have.

[fol. 458] Q. I understand that you do not claim to be a mathematical electrician, in the sense of being able to treat of the laws of resonance, like Kennelly does, for instance, in the article he refers to.

A. Yes; but I am afraid that my confidence in Dr. Kennelly is rather shaken by what you have just shown me. I am sure that he has come to a wrong conclusion about these circuits of mine which he has just discussed, therefore, whether he is a mathematician or not, like everybody else, he is apt to be wrong.

Q. Do you contend that you are as good a mathematical electrician as Kennelly?

A. I won't go into comparisons with you. I cannot answer that question.

Q. Well, he has given you, in the language you were asked about, he has given you the laws of resonance. You say you have not read them?

A. I am not a mathematician. Whether I am poorer or a better man, I am probably not at all as good as he, but I cannot take and compare myself with anybody else, on the witness stand, and you ought not to ask it.

Q. I think Kennelly and Fessenden both say your apparatus there does not radiate a wave with one predetermined frequency, and they give the reasons and cite the laws. What do you have to say?

A. They cite on premises which are wrong. They state that these circuits are tightly coupled, and that is not true. Of course, it is always a question of degree as to what is tightly coupled or loosely coupled, but taken in the ordinary phraseology of wireless telegraphy of the present day, those circuits are not tightly coupled.

Q. In your eight figures of your patent, all but two show the total construction of the coupling there between the coils of the transformers, and they say you have a tight coupling, and that when you have got a tight coupling, you cannot produce one wave, and therefore, you have not got a true four circuit tuning. That is a plain, frank statement

of what I think the defense shows. I want to know what your answer to that is?

A. I do not agree that these are tight couplings.

Q. And if they are tight couplings, they are right?

A. If they are tight couplings, they are right. You can get tuning between the four circuits just the same. If you radiate two waves and receive two waves, you can receive the same energy at the receiving station, whether the station is tightly coupled or not, the difference being that the tuning, that is, the elimination of interference will not be so good with tight coupling as it is with loose coupling.

Q. The loose coupling is the better?

A. In some respects it is better, and in others it is worse. If the coupling is too loose, you are throwing away energy at both ends, at the receiving end and at the sending end.

Q. Haven't you testified that you were the first to produce a wireless telegraph apparatus at which there was here an open circuit and here a closed circuit inductively coupled to it?

A. I think I was the first to try it, but simply stated like that, the thing didn't work. The two circuits had to be tuned to each other.

Q. Fessenden said that in 1899 he had this circuit that I have put on my little sketch, and used it. What is the electrical difference, if any, between that sending station shown on my little sketch and yours there, supposing this to be a spark gap, making an oscillating circuit, what is the [fol. 459] electrical difference, essentially?

A. The electrical difference is that my circuit is tuned to it, the closed circuit E-D has to be tuned to the open circuit, earth E-A. In the other sketch at the top of the drawing, I do not see that anything is tuned to anything else at all. I don't know what description goes with that figure, but there is nothing shown that is adjustable, no means for adjusting the two circuits, one to the other, and I doubt very much, I would like to know how those circuits can be tuned so as to have the same period.

Q. Suppose you were told to build a wireless telegraph apparatus in which that local closed circuit was to excite the antenna?

A. This (indicating)?

Q. No, in my sketch. You were told to make a local closed oscillation circuit so that it would excite the radi-

ating antenna, wouldn't you inevitably make them so they had the same electrical period?

A. In view of the knowledge of the present day——

Q. No, in view of the knowledge in 1899?

A. I would not know what to do with it.

Q. Do you think it would be possible for anybody, in 1899, with their then knowledge? Suppose, for instance, you had telegraphed across the British Channel, and with your own knowledge as a consequence, would you not on being told to build an apparatus and cause the radiation to be excited by the local closed circuit, do you think it possible that you would build them in such a way that they did not have the same time period?

A. I would have nothing to go on to show that they should have the same time period.

Q. You said they were the same time period?

A. No, sir; I did not.

Q. You said forced oscillation?

A. Mr. Clay, please do not make me say something, or attempt to make me say something I have not said.

Q. I thought a forced oscillation was an oscillation that was perfect?

A. No, sir. It is due to your incomplete knowledge of the subject.

Q. It is just like taking a spring with your hand and forcing it back and forth?

A. It is forcing it to do something it is not willing to do.

Q. Now, that force cannot be out of tune with the forcing power?

A. Not at all.

Q. Then whenever there is a forced oscillation in either one of those circuits it has got to be an oscillation in time to the force that is moving it?

A. Yes, sir; but that is as different from tuning as night is from day.

Q. Now, my question is, would you make those two circuits, would any electrician build those two circuits in such a way that that creation of oscillation in one circuit by the oscillations in the other would be out of tune so that they would interfere instead of working? That is my question.

A. I think that is what would have happened if that circuit had been tried at that time.

Q. Everybody knew at that time that the time period of this local circuit was dependent on the value of the condenser in the coil.

Q. They also knew that the time of oscillation in the antenna was dependent upon that condenser A-D?

A. No, sir.

[fol. 460] Q. And the coil?

A. No, sir; they didn't know anything of the kind. It is all mixed up between the two circuits as to what is the period of each.

Q. Did you see the exhibit which shows Fessenden's publication of September 16, 1899, before you testified?

A. I would like to see it in order to be able to answer the question. Yes, sir; I saw it some time ago.

Q. Do you consider that that shows two forms of loose coupled transformer at the receiving station? Or do you think that the third figure does not show a loose coupling? Of course, I suppose you have no question but that the second one is a loose coupling?

A. I cannot say as to No. 2, whether it is a loose coupling or a tight coupling. I don't know what transformer it is referring to, whether there is iron in it, or not, and what is the length or the dimensions of the circuit connected to it.

Q. I thought you understood that is a glass tube there. That is, two coils of wire on the glass tube sliding to and from each other. There is no iron there; it is an air core transformer. The question is whether that shows two forms of loose coupling or only one.

A. I should say the second figure shows some form of transformer. I really, I cannot say whether it is loose or tight. It is not very tight, but I cannot say whether it is very loose.

Q. What about the third figure?

A. The third figure shows a coil shunted by a condenser with a coil, a galvanometer coil inside of the coil I have just mentioned. I do not see that that can be called a transformer. I think it is a form of galvanometer.

Q. In your patent in suit, is there any possibility of physically moving the primary and secondary of the transformer with respect to each other?

A. No.

Q. Dr. Fleming is the scientific adviser of the Marconi Company, isn't he?

A. He is one of the scientific advisers.

Q. He is a prominent authority in England?

A. Yes.

[fol. 461] Q. In 1899 were loose coupled transformers used at all?

A. Excuse me; for what purpose do you mean? Any purpose?

Q. The purposes of the patent in suit; for instance, wireless telegraphy?

A. I think some were used in some receivers which I constructed.

Q. You think only in your own work?

A. That is all I know of.

Q. Do you think there is any meaning to the statement that a transformer may be a loose coupling in one direction and tight coupled in the other?

A. I don't follow your question.

Q. Could the transformer be loose with respect to the transfer of energy in one direction and tight with respect to the transfer of energy in the other direction?

A. It might be so if it had a saturated iron or steel core in it, but I do not quite see how it could be so if it had not.

Q. I mean, supposing your local circuits were transferring the energy through the transformer into the antenna in the one case, and in the other, supposing there were a circuit passing through the antenna and into the local circuit, could the same transformer be loose coupled in one instance and tight coupled in the other?

A. No, sir; I don't think it could.

Q. The adjustment of the tuning coil in the transmitting station is a step by step adjustment in your patent, is it not?

A. It may be, or it may be a circular movement, continuous adjustment. It is exactly, I suppose, as it is described. I don't remember the exact description of that.

Q. I want to get this chart right, because I do not think it is clear. That ought to be represented as a lot of leads coming out here so that it is changeable step by step, and not turn by turn. Look at the patent and see if that is not true.

* * * * * * *

A. No, sir; I don't think the patent shows that.

Q. Well, I understand you to agree to that, if the coupling is tight in your sending station there would be radiation two waves and not one?

A. Yes.

Q. Then how could there be four circuits tuned to the same period? Which of those two periods would it be?

A. If you take the two circuits separately, separate them from each other, you will find they are tuned to the same period.

Q. Well, which period?

A. The period of each other.

Q. There are two waves being radiated, wave A and wave B; to which one of those are your four circuits tuned?

A. When the circuits are separated they are tuned to a wave that is intermediate between those two; but they are nevertheless tuned to each other. The product of the capacity by the self-induction in each circuit will be equal.

Q. That is what I want the Court to understand. The effect of this coupling is to change the tune of each circuit?

A. If coupled very tight, but if it is loose that effect will be negligible.

Q. It vanishes gradually?

A. Yes, sir.

Q. But a close coupling, or anything approaching a close coupling, will make it necessary for the wave actually radiated not to be in harmony with either the antenna or the local circuit, isn't that so?

A. That is if the coupling is very tight.

[fol. 462] Q. Yes.

A. But that is not the case of this patent.

Q. Now, when you say the four circuits are tuned to a particular wave length you mean a wave length which is not being radiated, don't you?

A. No, sir, I don't mean anything of the kind, because I have stated that in this case you are considering in the invention described in the patent in suit, the circuits are loosely coupled, not tightly coupled, therefore they radiate one wave, and the two circuits have the same tune and the same period.

Q. There is a difference of opinion and the defendant's witnesses give a mathematical demonstration and you do not answer it. We will suppose at least that they are right. If they are right, how can there be four circuits to the particular wave when there is not any particular wave?

A. Assuming that they are right, and I am certain they are wrong, because we have taken measurements in regard to the coupling of those circuits, but assuming they are right, the period of the two circuits taken independently would still be the same. The product of the self-induction by the capacity would be the same in both cases.

Q. But in actual work——

A. In actual work, two waves would be radiated.

Q. And the waves radiated would not be of the periodicity of either one of your sending circuits, would they, or would they not?

A. If the coupling was tight it would differ from the period of the two circuits by a certain percentage. Each wave would differ a little bit one way and a little bit the other.

Q. And that does not interfere with your object of selecting of a station?

A. No, sir; but I have not shown in the patent, nor do I use, tightly coupled circuits; therefore, it is a condition that does not arise.

Q. The radiation of two waves would certainly be, if not fatally, very deleterious to a receiver which made a response in proportion to the energy radiated, wouldn't it?

A. No, sir. If the coupling at the receiver is also tight the receiver will receive or will integrate the energy of the two waves.

Q. And it will be tuned to which one of them?

A. To both of them.

Q. To both?

A. To both.

Q. Its time period will be the same as both waves?

A. The time period will be such as to respond to both.

Q. But not exactly either?

A. Well, what do you mean by not exactly either?

Q. Why, Mr. Marconi, Mr. Fessenden says that exact tuning is not possible with your apparatus, and I am trying to find out whether he is right or wrong. You say that there are two waves radiated. I assume that there are two waves received.

A. I am only assuming that there were two waves radiated just to enable you to go on, but I am not accepting that as a fact.

Q. I appreciate that, but all this on the assumption that there are two waves radiated now?

A. Yes, sir.

Q. When you come to the receiving station, are those two circuits tuned to the same time period?

A. They are.

Q. If they are, it is not the time period of the wave received, is it?

A. Why not? Are you still assuming a tight coupling?

[fol. 463] Q. If they are, it is not the time period of the wave received?

A. Why not? Are you still assuming a tight coupling?

Q. I assume that two things that are alike cannot be like two other things which are different.

A. Are you assuming a tight coupling?

Q. Yes.

A. In that case with a tight coupled receiver, the tuning would certainly not be as good as with a loose coupled receiver, but due to the fact that the tuning is not so good, the energy of the two waves will be received, I think, with a pretty high degree of efficiency.

Q. But there is not any four circuit tuning of one particular definite wave, is there?

A. The four circuits, if you take the four circuits, they all have the same time period, whatever happens to the wave.

Q. That is, when they are not working, but when working?

A. Taking the assumption of something which I do not use and which I do not describe, I think that would be a fact.

Q. That is, they are not tuned to any particular one wave?

A. The circuits themselves are tuned by the waves which are transmitted and received, differ slightly from the periods of those circuits.

Q. I want to get some definite figures, because this seems to me a very important point. Assume a wave length, of whatever is a convenient number, 1,000 meters?

A. Yes, sir.

Q. And your other wave you may assume what you please, what would it be, 1,100?

A. Well, put it like that, 1,100, yes.

Q. Is that a likely assumption?

A. Yes, sir.

Q. Now, you have a reduction of a wave 1,100 meters to a wave 1,000 meters?

A. Yes, sir.

Q. What is the time period of the sending antenna, in its position and while it is radiating?

A. It will have both periods of alteration.

Q. It will be first tuned to one and then to another?

A. Yes, sir.

Q. What changes the tune?

A. The reaction between the primary and the secondary circuits. It will be caused by this circuit pushing that, and it has a certain frequency, and then part of the energy goes back again if the coupling is too tight.

Q. And that is the result of the tight coupling?

A. That is the result of the tight coupling.

Q. If you had a loose coupling it would only radiate one wave?

A. Yes, sir.

Q. And in that circumstance you could have a local circuit and antenna both exactly in tune with the wave being transmitted?

A. Yes, sir.

Q. And in that case you could get a response which represented the sum total of all the energy in all the waves that were radiated, couldn't you?

A. You will get tuning. I don't say you could get the sum total of all the energy radiated, or that you would get very high efficiency if the coupling is very loose, because the receiver becomes less efficient in consequence of the loose coupling. The energy does not go through from one circuit to another so well when the coupling is loose, and when you use the spark it couldn't get through quick enough; therefore, a very loose coupling will reduce the efficiency of your receiver.

Q. In your patented apparatus, your object is to build up as high a voltage as you can for the terminals——

A. The object is to establish resonance in that circuit [fol. 464] to build up the voltage sufficient for what is necessary to make the coherer act.

Q. That would be done when you were working with two waves almost as well as when you have got one wave? You build up a voltage there notwithstanding you have got two waves?

A. If the coherer circuit is closely coupled it is easier to get up a potential, even if it is not tuned very accurately.

but with the coupling given in the patent the tuning is and can be proved to be good.

Q. Now, suppose that in this defendant's device, suppose that I am correct in saying that every pulse of the current in the secondary current takes effect wave by wave, every pulse without exception takes effect on the receiver, do you think that could possibly be done if you had the two waves?

A. I don't see why not.

Q. There could not be two waves of the same period, could there?

A. There can. If they are the same period they are the same period.

Q. They are the same wave?

A. They might be.

Q. If there were to be two waves to take the circuit, it could not be tuned to both?

A. If they are tight coupled they will both go through.

Q. I didn't ask you whether they would be. I asked you whether they could be tuned to both when the two are different? It seems to me an axiom that if two waves are different you cannot tune the both of them in the same circuit.

A. Depends on what your circuit is.

Q. Suppose it is the circuit shown there, practically a simple oscillating circuit?

A. I think the detector there, whatever it is, would be affected by the two waves if the two waves were there.

Q. And the two waves would be operating in a circuit tuned to which one?

A. Tuned to either or tuned to an intermediate between them.

Q. Well, which one? Call them A and B. Which one?

A. Anyone you like.

Q. Assume one?

A. If the circuit is tightly coupled and if the damping circuit is great it would be affected by one or two waves or maybe ten waves, that happened to be going around that circuit.

Q. I don't think we are getting anywhere, Mr. Marconi. The circuit cannot be tuned to two things which are different, can it?

A. A circuit can be, a good resonant circuit which is very exclusive and which only wants one wave and which does not want any other wave.

Q. And that is what you call good tuning?

A. But the circuit may be, and that circuit looks very much like it, a circuit that is not at all exclusive or particular, a circuit that will respond to anything. A circuit that is very universal in its likes and in its sympathies. In that case even if you are a bit out of tune the wave will affect it substantially the same.

Q. The more universal its likes, or just in proportion to the universally of its likes, it fails to be well tuned, doesn't it, to anything?

A. It certainly is not a good tuned circuit if it will respond to a very large range of waves, and without differentiating between them in a definite manner.

Q. The commercial use of your invention that you have testified to all took place between the filing date and the issue date of your patent, didn't it?

A. Between the filing date——

[fol. 465] Q. Between the filing date and the issue date of your patent, that is, between November, 1900 and June, 1904?

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A. No, sir, I do not agree with you.

Q. Well, I may be mistaken about your dates.

A. It is not the date——

Q. To what dates did it run?

A. Run what?

Q. The commercial use of your invention?

A. It commenced in 1898, I should say, or 1899, the British Navy began to use it; 1899 it was used for important New York yacht races—excuse me, are you speaking of the patent in suit?

Q. Yes. I understood you to say the first use in the United States was August, 1901, at Nantucket?

A. The patent in suit, yes. You asked about my invention and I took that generally.

* * * * * * *

[fol. 466] Q. At how early a date did you introduce into this country knowledge of a system having an open circuit and a closed circuit at each station, the four circuits being tuned to the same electrical time period?

A. Some time in 1900.

Q. 1900?

A. Yes.

Q. Do you still regard as your invention the combination of four circuits having the same time period?

A. Yes, I do.

Q. That is, your idea of your invention is that it is a closed oscillating circuit at the sending end, connected to an open radiating circuit and at the receiving end, an open absorbing circuit connected to a closed operating circuit?

A. Yes, the circuits being in resonance.

* * * * * * *

Q. Let us get the Court clear on that resonance question. Does that mean anything else than that those four circuits are so adjusted that when an electric pulse flows in them it takes the same time to flow through one as it does through the other three? It simply means that they are [fol. 467] timed together, like my illustration of the boy on the spring-board, isn't that right?

A. I cannot accept your definition. I would rather put it my way. They are tuned so as to have the same, or substantially the same time period. They are tuned, if I might put it this way, so as to be in tune with each other, but the sound principle underlying the system in the invention is that all four circuits should have the same period of electrical oscillation, and I think it is so expressed in the patent, in this way: That the product of the capacity multiplied by the self-induction should be the same in each circuit.

Q. When I tried to get you to state the laws of resonance you refused to do it. Now I want it stated in plain every-day English, isn't it that the electric pulse flowing in the circuit takes the same time to travel in one circuit as in the other?

A. I don't know what you mean by electric pulse.

The Court: Then describe what you mean by time period.

A. Well, every circuit that is resonant has an electrical period of its own; has, as we would call, a time period.

By the Court:

Q. That is the time it takes to go through, isn't it?

The Witness: It is not the time it takes to go through. I object to the word pulse because it is not really a pulse; it is a wave, it is longer than a pulse.

The Court: Then substituting wave for a pulse, would you agree with the statement counsel makes?

A. Yes. It takes a certain time for each complete oscillation to go around that circuit. For example, we may have a circuit in which the electricity oscillates one thousand times a second, in which it completes a thousand complete oscillations to a second, and another circuit in which the electricity will execute say only five hundred oscillations to a second. The period of those two circuits is very different,—different from each other.

By Mr. Clay:

Q. I want the Court to understand that it is because the electricity takes a longer time to traverse the circuit.

A. Because the circuit is electrically longer. — In other words, in 36-A, the sending station of the patent in suit, in the righthand sketch, any manifestation of the electricity which traverses that red circuit from one side of the condenser around to the other side it takes the same time to do it as a pulse of the electricity moving from the earth up to the top of the antenna?

A. And back; yes.

Q. And back again in either one?

A. Yes, sir.

Q. What other movement occurs in either of those circuits does in the same time?

A. Yes, sir; with the same time period.

Q. In your patent 627650, you say, at page 1, line 32:

"It is desirable that the induction coil should be in tune or syntony with the electrical oscillation transmitted." Notice the words "the induction coil in tune or syntony." What does that mean, except that the two members of the [fol. 468] induction have the same time period?

A It does not mean that there, at least I do not think it does, because I didn't know it at the time that this specification was filed.

Q. What is that date?

A. That date was the 5th of January, 1899.

Q. In 1899 you didn't know it?

A. I didn't know that it was necessary to tune the two circuits of the receiver or transmitter in order to attain those effects.

Q. See if this language does not describe the condition of affairs you have always supposed to be synchronism between these four circuits:

"The combination with the transmitting instrument, comprising a transformer, having its secondary connected to ground and to an elevated terminal, respectively, and means for impressing electrical oscillations upon its primary, of a receiving instrument comprising a transformer having its primary similarly connected to the ground, and to an elevated terminal and a translating device connected with its secondary, the capacity and inductance of the two transformers having such values as to secure synchronism with the impressed oscillation."

If that fails to describe what you have got there in that chart 36-A, as showing the invention of your patent, 763-772, point out wherein it fails.

(The paper was handed to the witness.)

A. I think the idea expressed in that paragraph has nothing whatever to do with the idea of the invention shown in the patent in suit. What I think he means here, whoever is the writer of this, is that he is impressing electrical oscillations upon the primary of a transformer, and everything has got to be, at least, a transfer has got to be in synchronism with the impressed oscillations. It seems to me that he speaks of a transformer here; it must be connected to an alternator, an alternating current dynamo which works at a certain frequency, he is thinking of tuning his transformer so as to take up those impulses, or in other words, to be in synchronism with the impressed oscillations which are coming from the machine, which is not mentioned in the paragraph.

Q. But whatever movement of the electric there is in any one of the four circuits moves with the same speed, has the same time period, has the movement of the electricity in any of the four circuits, does it not?

*   *   *   *   *   *   *

The Court: Which one are you referring to?
Mr. Clay: The one he has just described.

* * * * * * *

[fol. 469] A. No, sir; it is not stated in that paragraph.

By Mr. Clay:

Q. What did he mean by this expression: "The capacity and inductance of the two transformers having such values as to secure synchronism with the impressed oscillation?"
What does he mean by the capacity and inductance of the transformers of having such values as to secure syntonism?

* * * * * * *

A. I would really have to read the whole article. The whole patent. It looks like a patent. I really don't know what he means.
Q. I want to see if you can answer as a pure matter of description. I will change the question. I want to know whether, simply as descriptive language, speaking to an electrician who knows what a transformer is, when a man says that the capacity and inductance of the two transformers have such values as to secure synchronism with the oscillations impressed on one of them, does not that mean that those four circuits are tuned together?
A. If he said circuit it would be different, but he says transformers.
Q. That is just what you said in your patent, in your patent of 1899, I think that is just the expression you used.
A. I just told you that I didn't mean tuning of the circuits.
Q. You said it is desirable that the induction coil should be in tune or syntony with the electrical oscillations transmitted. The induction coil includes two circuits, does it not?
A. Yes, sir; but I did not mean that there. The circuits in the transformer as shown in that patent are not tuned, at least the closed receiving circuit and the open absorbing circuit are not tuned to each other, and it was not conceived at the time of that patent that they should be tuned to each other. What I meant by saying the induction coil is tuned there was that the period of its primary, the pri-

mary period of the coil which was connected to the aerial should be such as to make the period of that circuit—by circuit I mean a coil in the aerial—such as to be in tune with the other station, but I had not conceived at that time that the two circuits of the transformers or the two receiving circuits, to be more accurate, should be in tune with each other. It is not described there, and I do not take it to have the meaning which you suggest it has.

[fol. 470] Q. When you say the induction coil is in tune or syntony with the electrical oscillations, the word coil refers only to the secondary?

A. To the primary there. I don't know what you call primary and secondary. I call the one attached to the antenna the primary.

Q. Oh, no. Well, if you are going to take the other end of the station, very well. You say in this passage the induction coil should be in tune or syntony with the electrical oscillations transmitted. You say that means the primary?

A. Oscillations transmitted are the oscillations coming from the station from which you want to receive.

Q. And the oscillations coming are certainly in tune with the sending antenna, aren't they?

A. Not necessarily. They are, I think, in that case, yes.

Q. Could they be anything else?

A. It might be a forced oscillation.

Q. Oscillations must be in tune with the sending antenna, must they not?

A. They are.

Q. Well, they must be. They cannot be anything else?

A. You must not say must in questions like this. They are. There is very little must about electricity.

Q. Explain how you would get a million a second off an antenna that was not tuned to a million a second.

A. You might have forced oscillations from a generator of some kind which would not be very efficient, but not commercially useful, but take a million a second of something that was not tuned to a million a second—that is not what we are discussing. The oscillations which we are receiving are certainly of the period of the transmitting wire. I think we are in agreement over that.

Q. Now, your remarks about impressed oscillations just now show that they must be in tune with the impressing source?

A. I don't follow your line at all. I am sorry.

Q. That patent says the receiving antenna is in tune with the sent oscillations.

A. It does not say that. Which patent?

Q. Your patent 627,650, page 1, line 32. It certainly says that the receiving antenna, including the primary induction coil, is in tune with the oscillation sent, does it not?

A. Thirty-two?

Q. Yes.

A. It does not say that. What it says is it is desirable that the induction coil should be in tune or syntony with the electrical oscillation transmitted. That is what it says.

Q. And you say that means the coil corresponding to this coil J′ in your Chart 36-A is tuned to the sent oscillation.

A. What that means is that you have a definite length so as to make the whole circuit in tune with the received oscillations.

Q. If it is in tune with the sent oscillations it must be in tune with the sending antenna?

A. Yes, sir.

Q. The sending antenna, in order to have oscillations produced in it, must be in tune with whatever is producing the oscillating current?

A. At that time, there was nothing except a spark gap to produce the current.

Q. When the current impressed itself onto the antenna——

[fol. 471] A. It never did it before the date of that patent, or at the date of that patent,—this patent, 627,650 applied for on the 5th day of January, 1899.

* * * * * * *

Q. Now, I show you a drawing that is described in the language I have been quoting to you, and which you will see is a patent of Tesla in evidence. Look at the drawing alone, please, and let me read you another description and see if it does not define a four-circuit tuning. That one is Exhibit No. 6. The quotation is this:

"It will be readily understood that when the above prescribed relations exist, the best conditions for resonance between the transmitting and receiving circuits are attained and, owing to the fact that the points of highest potential

in the coils or conductors AA are coincident with the elevated terminals the maximum flow of current will take place in the two coils and this further necessarily implies [fol. 472] that the capacity and inductance in each of the circuits have such values as to secure the most perfect condition of synchronism with the impressed oscillations."

Now, I want to know wherein that fails to describe four circuit tuning.

A. Do you object to my reading that patent?

Q. Reading it on that drawing only.

A. Do you object to my reading it myself?

Q. No; I do not want you to read it. I want you to hear the language and see if the language is not a description.

* * * * * * *

A. I cannot answer that question intelligently, because it refers to other conditions which you do not state at the beginning of the paragraph, and I really have got to know more about it. If you will let me read more of the patent, and try to find out what he means, I may be able to give you an intelligible answer. If I answer like this I may give an answer which is not accurate. I do not understand what he is driving at in that paragraph.

Mr Clay: If your Honor please, I don't know whether I have actually put in evidence Tesla's patent 649621, which is a division off of our Exhibit 6, which is patent 645576. For fear I have not, I want to offer in evidence now the Tesla patent 649621, dated May 15, 1900, divisional application being February 19, 1900, divisional application 650343 of September 2, 1897, which is the application for patent 645576, Defendant's Exhibit 6, and ask to have this divisional patent marked Exhibit 6-A.

* * * * * * *

[fol. 473] By Mr. Clay:

Q. In the apparatus of your patent in suit, would it make any difference if the transformers, instead of being constructed as you have shown them, were constructed as in Defendant's Exhibits 6 and 6-A?

A. I don't know how they are constructed here. They do not look like operative transformers. I cannot answer that

question. I don't know whether it is a transformer, or whether it is a plate, or what this thing is I am looking at. I would have to read the specifications, but you won't allow me to do that; therefore, I cannot tell you.

• • • • • • •

[fol. 474] Q. Would your invention of the patent in suit, as you understand it, be embodied in the apparatus I show in my sketch 2, provided the antenna circuits, both of them, and the local circuits, both of them, were closed, and the local circuits being enclosed, were all four tuned to the same time period?

A. What do you mean by closed? Do you mean no spark gap?

Q. You testified the other day that a circuit with a spark gap was closed, didn't you?

A. Yes; I did; but if a spark is there you get a certain effect which you do not get if there is no spark.

Q. I am referring to that feature of your invention, or supposed invention, which involves the tuning in unison of four circuits without regard to how the current works, except that it is a transmission system for intelligence by oscillating current.

A. You give me a circuit that won't work, I cannot say that it is covered by my patent or intended to be covered by my patent.

Q. Do you know any reason to suppose Tesla's patents and publications do not describe what is on my sketch 2?

A. No, sir. I do not see anything in Tesla like your sketch at all.

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[fol. 475] The Court: Mark that Exhibit 49. It is the same sketch that you have referred to in the complainant's map, but we must know what the witness is talking about.

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By Mr. Clay:

Q. Will you look at Defendant's Exhibit 6 and see if that transformer is what you were describing yesterday as a loose coupled or tight coupled transformer?

• • • • • • •

A. I must read a little to understand it. Looking at this exhibit I should say that the transformer shown, if it is a transformer, or rather the circuits shown, are very tightly coupled. That is my impression. I would have to read it carefully to be absolutely certain. The patentee speaks of obtaining very high voltages, hundreds of thousands or [fol. 476] millions of volts, which are absolutely useless in regard to wireless telegraphy. But, in order to obtain these high voltages, I think it would be necessary for him to use a very tightly coupled transformer, and I think that is what he has shown.

Q. Well, suppose two circuits tightly coupled, do I understand you to admit that you cannot tune one, we will say to the frequency N and the other to an octave higher and have them co-operate?

A. You can tune one to an octave of the other. You cannot tune the other one to an octave of itself, because otherwise it would not be an octave of its own fundamental period.

Q. What relation is the time period of a wave that is an octave higher than the wave of the period N?

A. In wireless it would be generally as 50 say to 150.

Q. Where did you get that definition of an octave?

A. I got it from the results of my experiments.

Q. It is a new definition of octave?

A. It is a definition of what occurs.

Q. Did anybody other than you ever hear of an octave being anything else than a note which has twice as high a frequency?

A. Yes. That is correct. That is, what I am referring to, is a harmonic really. An octave would be double, as you say.

Q. You could tune to a third harmonic, but not to an octave?

A. It can be made to oscillate to an octave.

Q. I didn't ask you that. Please hear my question repeated and answer. I didn't ask you if it could be made to oscillate. I want to know if you can, in your apparatus, tune the antenna an octave higher than the excited circuit?

A. That is a question, is it?

Q. That is a question?

A. Yes, you can.

Q. And get good radiation?

A. No, sir. The radiation will not be as good as if it is tuned to the fundamental.

Q. Then if you do tune it to an octave, as you suggested in your patent, it would not work?

A. I do not recommend it in my patent. I stated that it can be done. It does work, but it will not work so well as when it is tuned to the fundamental, or when it is tuned in the way I describe all through the patent.

Q. In the case of tuning the octaves you have just mentioned, you would get your time period varied between waves, wouldn't you?

A. I don't understand what you mean, time period varied between waves.

Q. Supposing you have got a tight coupling and suppose you have tuned to an octave, wouldn't you get two waves instead of one and an unequal time period between waves?

A. If the coupling is tight, very tight, you certainly would get two waves. I do not understand what you mean by a difference in the time period between waves. I don't see that.

Q. Did your original radiator send out more than one wave, or not?

A. What do you mean by my original one? The patent of 1896?

Q. Yes.

A. That I should say sent out one wave.

Q. What about the original apparatus of this patent in suit that you have described using?

A. That sends out one wave.

Q. One wave?

A. Yes.

Q. Is it not a fact that all your stations now send out a double wave?

[fol. 477] A. Not unless it is intended that they should do so. I have never heard of that. I do not agree with you. We can send out five waves if we wish to.

Q. Can you send out a single pure wave with the use of the apparatus in suit?

A. Certainly.

Q. You think that your stations do that?

A. I am absolutely certain of it. We have got to do it under the prescriptions of the British Admiralty in England. If you send out more than one wave, unless you are

licensed to do so, you are called upon to stop. Also, on board ships which work under the international convention on wireless telegraphy, you have got to send out one wave and one wave only, and the apparatus we use is the apparatus which we have been talking about.

Q. I want to be quite sure that you understand what I mean. I will put on the corner of the chart a little sketch of a wave with a double hump. Do you deny that your station sends out a double humped wave?

A. Absolutely and most decidedly. I should add to that, that stations can be made to send out a wave like that, but it is not done unless it is for particular purposes.

Q. Do your stations send out a wave which is resonant to two frequencies?

A. I don't understand a wave that is resonant to two frequencies. You mean two waves?

Q. No.

A. A wave is not resonant to anything. It is a circuit that is resonant.

Q. Didn't you say yesterday that the two coupled circuits, closely coupled circuits, could be tuned simultaneously to more than one wave?

A. What? No, I did not.

Q. Tuned simultaneously to more than one wave?

A. No, I said a receiving circuit could be tuned to have a broad range of tuning and be affected approximately equally well by two waves which do not differ too much from each other. That is what I said or meant to say.

Q. Did not Prof. Fleming demonstrate that if you have two circuits, each of which is carefully tuned to the same frequency, then bring them together and couple them, they have neither of those frequencies acting together?

A. No; I don't think he showed that. I do not agree with you.

Q. Taking the Chart 36-A, either one of the figures showing the patent 763772, suppose you tuned the red circuit to the frequency N and the black circuit to the frequency N, entirely separate from each other, now you couple them together, what will be the frequency of the radiated wave?

A. If they are coupled loosely it will be the frequency N.

Q. And if tightly?

A. Two waves will be radiated.

Q. Will that be N and N?

A. That will be N and N.

Q. Will either one of them be the frequency N?

A. No, sir.

Q. In other words, when they are coupled, the frequency of the combination is not the frequency of either one of the circuits separately?

A. The frequency of each circuit remains the same, but the frequency of the wave given out, due to the reaction of the two waves is different from the fundamental, always when the coupling is tight.

Q. Now, we have got three frequencies to deal with. The circuits themselves have the frequency N?

A. Yes, sir.

Q. The wave radiated has not the frequency N, but the frequency N^1, we will suppose?

A. Yes; and another one.

[fol. 478] Q. And the frequency N^2?

A. Yes, sir, if the coupling is tight.

Q. Now, we have got three frequencies. Go to the receiving station, to which of those three frequencies is your receiving antenna tuned?

A. There are two ways. One is to let your receiver receive both the waves, if two waves are radiated; and the other is to tune the receiver to one of those waves, that is, the longest or the shortest.

Q. What becomes of the other?

A. The other one goes loose. There is nothing done with it.

Q. It does no work, does it?

A. It does no useful work.

Q. Then in your apparatus there is no possibility of a cumulative receiver, in the sense of making a response by virtue of all the energy?

A. No, I am simply proceeding with you on an assumption of the fact that the coupling is tight.

Q. All of your testimony is based on the assumption then that the coupling in your patent is not tight?

A. No. The examples given in my patent, all of them are loose. If they were tight, I do not think—or if they were very tight—which is not shown in any of the examples—I do not think it would depart from the principle laid down in the patent, because you would lose the energy of one wave, but still you could tune perfectly well through the other wave, and get the cumulative effect from whichever

wave you were using, which would be what we may call a tuning effect, and also extremely useful, and an advance on what was done before.

Q. You seemed to me to testify that your wireless telegraph system was a gradual development. Now, in that development, which came first, this four-circuit tuning idea, or the use of the transformer at the two stations?

A. The four-circuit tuning idea came at the same time with the idea of the transformer at the two circuits, so far as I am concerned.

Q. The transformer at that time was old and well known, was it not?

A. What transformer?

Q. Any transformer in a system of sending energy by electro-magnetic waves?

A. Not connected that way.

Q. Why, Lodge in 1898 had a transformer, did he not?

A. He had a transformer in his receiving circuit. I do not see any in his transmitting circuit.

Q. And you are neglecting Tesla and Thomson, and all the whole tribe of Americans?

A. I do not see—I have not been shown that Tesla or Thomson described any transformer at all.

Q. The point is, the use of the transformer came at about the same time that you made use of the four circuits tuning?

A. No. If I have to answer you literally—you do not put your question so I can answer it easily.

Q. Answer it as you please.

A. I described a transformer in my first patent of 1896, applied for June 2nd, 1896. I speak of a transformer there. Therefore, I might say that I thought of a transformer at that time, and probably before that time, but what I am alluding to now is a transformer which is connected in the way shown in the patent in suit, and which is constructed in such a way as to be able to transform or to be operative with these high frequency currents which are used in wireless telegraphy, or which were used in wireless telegraphy at that time. That is what I understand to be a transformer. [fol. 479] Transformers were used a long time before, but they were different transformers, and they were used in a different manner.

Q. Do you think anybody, even in 1896, would have employed a transformer—and, mind you, it is a transformer of

alternating current— * * * and not make the two sides of the apparatus with the same period?

A. * * * I do not think that anybody knew about the tuning of the two periods at that time—the tuning of the two circuits of a transformer, at that time.

Q. You do not think anybody knew it was necessary to have them with the same time period?

A. No. There is nothing that I know of that suggests that.

Q. Now, this matter of the Nobel prize, that you testified about, that was divided between you and Prof. Braun, was it not?

A. No. The money part of it was divided—was given half to myself and half to Prof. Braun, but I had a full diploma and prize for physics, and a gold medal.

Q. Did he not have the same?

A. Will you allow me to finish?

Q. Yes.

A. And Prof. Braun had also a diploma and a medal, and half of the total sum of money.

Q. What is the distinction then, from my statement, that you divided the prize?

A. If you take the money as being the prize——

Q. (Interposing) Oh, no. I would not think of anything so mercenary as that, but the honor?

A. No. I was given a diploma with my picture on it, and several other things, and not a mention of Braun or anything to do with Braun, and that is the Nobel diploma. Braun was given one for himself, with his own picture on it, and nothing else that I know of. Therefore, I cannot say that the prize was divided between myself and Braun, because, in that case, we would have been given a joint diploma, I presume.

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Q. Is it not a fact that from the beginning there has been a prize in physics awarded every year?

A. Yes.

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[fol. 480] The Court: In this particular year that is referred to, Mr. Marconi, the fact is, as I understand it, that Prof. Braun—if he is a professor—and you received exactly similar recognition?

The Witness: Yes, sir.

The Court: And that the maximum prize of $30,000, so far as the money goes, was divided?

The Witness: Yes, that is absolutely correct. Except, I might add this, if I may be allowed to, that I took precedence over him, in the fact of the prize being given first, and in the position amongst the prize winners, I took precedence over all the Nobel prize winners of that year, because the prize for physics is awarded by the King, and it was awarded first to me, and then to Braun.

The Court: But in the same sphere in physics?

The Witness: Yes, in the same sphere in physics.

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By Mr. Clay:

Q. Do you recall the fact that in the prosecution of several of your patents in the Patent Office you have discussed and made affidavits with respect to the Tesla patents?

A. With respect to what?

Q. The Tesla patents which were cited against you as references?

A. I made affidavits, do you say?

Q. I think so. Do you recall the fact that they were discussed in the file wrappers in several cases, and affidavits were made by you respecting them?

A. Yes, I remember that we had, through our patent attorneys, frequent correspondence with the Patent Office, in order to give explanations and to meet objections, and I know that I did execute several affidavits. I cannot say I remember the substance of them all, or that I am very clear on the substance of any of them, but I take it that what you say is a fact.

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[fol. 481] Q. But I want to ask you to point out, if you can, where you show the conductor coupling in the original patent—the use of the transformer in your original patent, and then that is all. Take your time about it, and have it put on the record afterward.

A. My original patent?

Q. Are you willing to do that, without comment?

A. You mean my original American patent?

Q. I thought you meant the British, but it does not make any difference.

A. No. It is in one of those, I think. In the original patent, page 3—I mean, there may be other references; I am just giving the first I see—page 3, line 18.

The Court: Give the number of the patent, Mr. Marconi.

The Witness: Patent No. 12,039, of 1896, the British patent. At line 18, it is stated: "In the transmitting instrument R is an ordinary induction coil (a Ruhmkorff coil or transformer)."

By Mr. Clay:

Q. Where was that?

A. Page 3, line 18.

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Redirect examination.

By Mr. Betts:

Q. On page 266, you were asked, on cross-examination, whether the commercial success that you testified about utilizing the invention of the patent in suit, did not take place between the filing date of the patent in suit, and before the issue. Has the invention of the patent in suit been put into use by you or your companies since its grant?

A. Since its what?

Q. Since its grant—its issue date?

A. Yes, it has been put into use very extensively in all parts of the world, and it is used now in practically every wireless telegraph installation which is worked by the Marconi companies and their associates. I think I am right in saying that it is used on every ship that is equipped with wireless telegraph, or that my companies have equipped with wireless telegraph, and it is used at every shore station in every country where these stations have been erected, and I say that the number of installations runs considerably over a thousand.

Q. When were telegraph messages actually first sent between Canada and England, and who was present when those messages were transmitted?

A. The first messages were transmitted from Canada [fol. 482] to England in December, 1902, in the presence of

officers of the Italian warship *Carlo Alberto*, and including other persons, I might mention the correspondent of *The Times*, in North America, Dr. Parkin. These first messages consisted of telegrams sent by myself, by the Governor-General of Canada, and by prominent persons, to the King of England and to the King of Italy, and to other eminent or prominent persons in Europe.

Q. How did the American electrical profession take the achievement of this successful transmission of messages across the Atlantic in 1902?

A. The American Institute of Electrical Engineers gave a dinner in my honor in January, 1902, at which were present all the most prominent scientists and electricians of America. I might mention Mr. Edison—Mr. Edison was not present, but he sent a message—but Prof. Pupin, Prof. Elihu Thomson, and many others. At this dinner messages were received congratulating me on what I had done, from Mr. Edison, from Mr. Tesla, and others, and I should also state that a very laudatory address or speech was made in regard to what I had done by Prof. Elihu Thomson. All this is reported in the *Electrical World and Engineer* of the issue of January 18th, 1902, which I ask leave to put in evidence.

Mr. Betts: I offer in evidence the copy of the *Electrical World and Engineer* of the issue of January 18th, 1902, and ask that it be marked Complainant's Exhibit No. 49.

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(The publication so offered and identified was thereupon marked "Complainant's Exhibit No. 49," of this date.)

By Mr. Betts:

Q. Is there any other advantage in the utilization of the invention of your patent in suit except that of long distance transmission?

A. Yes. There is considerable advantage which is of extreme importance in the practical use of wireless telegraphy. That is, in making communications independent of each other, or, in other words, avoiding interference. The commercial application of wireless telegraphy is dependent, to a very large extent, on these messages not getting mixed up, when numerous wireless stations are working in the

vicinity of each other, and by tuning these transmitters and receivers to definite wave lengths, and by not only tuning them, but by being successfully able to tune them without interference, tapping and mixing up of messages is avoided. This is obviously essential to any wide commercial application of the system.

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[fol. 483] The demonstration of messages not mixing up, and of the independence of various communications, was first given by me to the English navy at the end of 1900, and was described in certain publications, which, if I were asked I could refer to.

Mr. Betts: That is all, your Honor.

Recross-examination.

By Mr. Clay:

Q. How many attempts did you make to telegraph across the ocean before you succeeded? How many sets of apparatus were built for that purpose?

A. I think I succeeded in getting messages across the Atlantic with the first or the second set, or not later than the second day I tried.

Q. Will you look at this pamphlet, describing Marconi wireless as it was in 1903, and see if that correctly shows your apparatus, and also whether it shows the chart you have put in evidence, on the back page?

A. You mean on the cover?

Q. I mean the whole thing.

* * * * * * *

A. The last page does show a reproduction of the chart you referred me to—at least, I believe it does. With regard to the remainder of the pamphlet, it shows a number of pictures—an artistic reproduction of stations and towers.

The Court: What is your question?

Mr. Clay: Whether it does not show his apparatus as it was in 1903.

The Witness: No, it does not. At least, I do not think it does. It shows pictures.

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By Mr. Clay:

Q. Does it not show your tower antennae as they are?

A. It shows the towers, yes.

Q. As you used them in 1903?

A. Not necessarily. It shows the actual towers as they were in 1903. I cannot say what apparatus it shows connected with them, because it is simply a picture.

Q. Just let me pick out the ones that you agree show your apparatus as it was. It may be shorter, perhaps, to pick out the ones that do not. Which ones of the pictures do you think do not properly show your apparatus as it was in 1903?

A. I will say that none of them show it. The definition "apparatus" is a lot of apparatus. Here is shown a tower, [fol. 484] which is part of the apparatus. Here is shown a field, which I suppose must necessarily be somewhere.

Q. Mr. Marconi, I wanted the Court to see the kind of antennae you used in 1903, and I will be frank to say to you that I expect to show that you had ideas of antennae which other people did not have and therefore, ideas of electric wave radiation which other people did not have.

A. Well, that helps me, if you intend to show that.

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My answer was that none of them show it accurately as it was in 1903, but the first picture, after my own portrait, shows the towers as they were—substantially as they were, not accurately—as they were placed in 1903.

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Q. The pages are not numbered, but take the photographs of the transmitter and receiver on the page that is headed "Simplicity of Apparatus." Is that a correct showing, so far as it shows anything?

A. It shows some apparatus there that resembles very much the apparatus which I used experimentally in 1895 or 1896, I believe.

Q. You think not as late as 1903?

A. No.

Q. Is that a photograph of you at your desk, with apparatus which includes a bell and coherer receiver?

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A. The picture represents me, I believe. I do not remember it having been taken on the *Philadelphia*. As to the apparatus on the table, one cannot say what the apparatus is very definitely. I think a bell and a relay are shown. The remainder of the apparatus might be anything. It is too small to be distinguishable.

Q. Have you any reason to doubt that these are true photographs of your stations at the places they say?

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[fol. 485] A. They are a reproduction—rather, they appear to be reproductions of photographs. I do not know at what time the actual photographs were taken, of course.

Q. Do you think this pamphlet could have been issued without the knowledge and consent of the complainant company, or some of its officers, or of yourself?

A. It certainly was not issued with my consent.

Mr. Clay: I offer the pamphlet shown the witness, in evidence, and ask to have it marked Marconi Cross Exhibit No. 3—rather, Defendant's Exhibit, Marconi Cross Exhibit No. 3.

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The Court: You may mark it for identification, if you wish to.

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By Mr. Clay:

Q. Do you deny that these are photographs of the complainant company's stations?

A. I neither deny nor affirm it. Certainly, the apparatus shown there is not the apparatus I was using in 1901 or 1902 or 1903. I am referring to "apparatus," understand, not to towers.

Q. About the middle of the book there is what purports to be a photograph of your wireless station on the steamship *Minneapolis*. Is or is not that a photograph of that station (handing pamphlet to witness)?

A. I cannot say. I have never been on the steamship *Minneapolis* in my life. It may be.

Q. You do not recognize your apparatus?

A. You did not ask me that. It certainly looks like some of the apparatus used at that time—that particular picture to which you have referred me.

Q. When was the apparatus put on the *Minneapolis?*

A. I cannot remember. In equipping hundreds of ships, I cannot remember the date of installation on any particular one.

Q. Near the beginning of the book there is what purports to be a photograph of the Marconi Trans-Atlantic Station at Wellsfleet, Cape Cod, Massachusetts. Is that a photograph of your said station?

A. I think it is a fair representation of the outside of the station.

Q. That was there in 1903, was it?

A. Yes.

Q. That shows the antenna you used at that time, does it not?

A. No, it does not. It shows the towers I used. It does not show the antenna.

Q. If anybody can see an antenna, it is the antenna you used there?

A. No.

[fol. 486] Q. I think I can see one. If it can be seen, it is the one you used there in 1903, is it not?

A. None can be seen there.

Q. They were strung between the tops of those towers, were they not?

A. Yes, they were.

Q. In 1903?

A. And they were extended to two other masts around there, that cannot be shown.

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Q. Will you look at this pamphlet of the DeForest Company, dated September 1, 1902, and state whether you saw it or otherwise knew of the apparatus DeForest was using as early as that.

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[fol. 487] A. I have never seen this before, which is a stock selling publication, and I do not think I remember having seen anything in connection with the stations he mentions here, at that time, or knowing anything about them.

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Q. Mr. Marconi, have you not claimed from the beginning to be the only man who has had any wireless telegraph?

A. Let me understand. What do you mean by "had any wireless telegraph"?

Q. Produced any.

A. No. I recognize that for certain limited distances Preece in England, and I think Trowbridge, in America, did transmit messages between places without connecting wires, by using these long extended wires at each place. I believe—I am not saying it myself, but I think it is admitted generally that I was the first to employ electric waves or high frequency oscillations for transmitting telegrams to a distance, without wires.

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Q. Did you not say, since you came to America this time to testify, that the Arlington Station—this defendant's station—"I think it will be found is mainly a Marconi station, although it has a Fessenden apparatus. The Federal Court of Appeals has already held that the main Fessenden patent is borrowed from Marconi and Lodge." Did you say that?

A. That statement appeared, I think, in what I said before the Parliamentary Committee in England. I did not say that when I came to America. I stated that, if I remember correctly, before the Select Committee of the House of Commons, which was investigating the question of wireless telegraphy.

[fol. 488] Q. Did you ever think that the Court had held that Fessenden's main patent was borrowed from Marconi and Lodge?

A. Yes, I think the Court of Appeals—I have not the facts here—held that one of the Fessenden patents or one of the Fessenden claims was invalid, because Fessenden had utilized Marconi's and Lodge's inventions. I cannot give you the number of the decision of the Court, but I could, if I am given time.

Q. Will you look at this copy of the *Marconigraph*, for June, 1913, and see if you are correctly reported in the Technical Committee's report of Mr. Marconi's evidence, at page 394 (handing book to witness)? Do you know anything about it?

A. I see it here. I have had nothing to do with putting it in.

* * * * * * *

Q. First, will you state if you know what that publication is, and whence it emanated?

A. It is a publication called the *Marconigraph*, edited by J. Andrew White, published in America.

The Court: Well, all that appears on its face. Do you know anything about it?

The Witness: I know that it is directed or it is controlled by the Marconi Company.

The Court: This complainant?

The Witness: I believe so, yes. This is the American publication.

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By Mr. Clay.

Q. Do you think it is safe to presume that they have given that report correctly?

A. They may have.

Q. I mean, in general substance. I do not mean the particular words.

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[fol. 489] A. Page 394, I think, may certainly be assumed to be correct, but I have not checked it, or I have not read it. I think that is practically correct.

The Court: Well, you may look it over at your leisure, and see if it is. Mark it for identification.

Mr. Clay: Now, I want to offer this last one in evidence.

The Court: Let the witness look it over at his leisure first.

Mr. Betts: I offer in evidence a certified copy of the file wrapper and contents of Fessenden patent No. 706735 and also certified copy of United States Letters Patent of Fessenden, No. 706736, which letters patent have been offered in evidence as Defendant's Exhibits Nos. 2 and 2-A, and ask that these file wrappers be marked respectively Complainant's Exhibits Nos. 50 and 51.

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(The papers so offered and identified were thereupon marked respectively "Complainant's Exhibit No. 50," and "Complainant's Exhibit No. 51" of this date.)

[fol. 491] It is hereby stipulated, subject to correction should error appear, that various uncertified copies of

United States and foreign letters patent, and the following publications, to wit, defendant's Exhibits L, M, N, Q, R, S, T, U, V, W, Y, A-1, B-1, C-1, E-1, F-1, G-1, H-1, I-1, J-1, [fol. 492] K-1, O-1, Q-1, S-1, T-1, U-1, V-1, W-1, Y-1, Z-1, C-2, D-2, F-2, G-2, H-2, J-2, K-2, N-2, A-4, B-4, C-4, D-4, E-4, F-4, G-4, H-4, I-4, J-4, K-4, P-4, Q-4, W-4, Z-4, B-5, C-5, D-5, E-5, F-5, G-5, I-5, J-5, K-5, L-5, M-5, R-5, G-6, H-6, I-6, J-6 and O-6, may be received in evidence with the same force and effect as though original copies had been offered, and that the same were published on the printed dates borne by the respective exhibits, or stated in the record at the time of the introduction of the exhibit.

It is also stipulated, subject to correction should error appear, that the following exhibits may be received in evidence with the same force and effect as though original copies had been offered, and that the same were published on the dates indicated thereafter: X, December, 1901; L-1, February 28, 1890; M-1, 1898; N-1, subsequent to July 1, 1896; X-1, 1898; K-6, 1910.

As concerns defendant's Exhibit I-2, it is stipulated that the quotation made by the witness Loftin on page 556 of the typewritten record is a correct quotation from a paper published in the transaction of American Electro-Therapeutic Association in New York, 1894.

In entering into the above stipulation claimant does not waive any objections heretofore entered on the record regarding said exhibits and in cases where said exhibit publications have not been objected to on the ground as being incompetent evidence as proofs of the facts stated therein, said objection is hereby entered thereto.

Dated July 7, 1925.

Richard A. Ford, Sheffield & Betts, Attorneys for Plaintiff.

Approved: Herman J. Galloway, Assistant Attorney-General.

C. V. Edwards, Special Assistant to the Attorney General, for the Defendant.

Deposition of John M. Miller for defendants, taken at New York City commencing on the 30th day of March, A. D. 1923

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John M. Miller, having been produced as a witness on behalf of the defendant, was by me sworn before any question was put to him to tell the truth, the whole truth, and nothing but the truth relative to the said question, and thereupon deposed and said that his name is John M. Miller; that his occupation is radio aid in the Bureau of Engineering, Navy Department; that he is 40 years of age; that his residence is Washington, D. C.; that he has no interest direct or indirect in the claim in controversy; and that he is not related to the plaintiff, and thereupon the said John M. Miller was examined by counsel for the defendant and in answer to interrogatories testified as follows:

Direct examination.

By Mr. Edwards:

1. Question. Please state briefly your education and experience in the wireless telegraph and telephone art, having particularly in mind the vacuum tube development of that art.

[fol. 493] Answer. I was a graduate of Yale University in 1904, receiving the degree of B. A. From 1904 to 1907 I was a student in the graduate school of Yale University and also an assistant instructor in the physical laboratory. I specialized in the study of physics. In 1907 I received a degree of master of arts in Yale and later, in 1915 received the degree of doctor of philosophy in Yale. From 1907 until August, 1919, I was employed as assistant and associate physicist in the Bureau of Standards, Department of Commerce, Washington, D. C. For the last seven or eight years I have been engaged in radio research and testing work for the Bureau of Standards. About six or seven years ago I became interested in the theory and operation of different types of vacuum tubes. I started this work at the Bureau of Standards, and when the work became of importance I was put in charge of that branch of the work. During the war a great deal of the research and testing work on these tubes was transferred from the Signal Corps to the Bureau of Standards and I was in charge of this work. My work now is practically such as to be entirely concerned with vacuum tubes, so that I may call this to be my profession. I am at present assigned to duty at the radio naval research laboratory at the Bureau of Standards, and

I am in charge of the vacuum-tube section at that laboratory. In the course of my work I have examined and operated many different types of vacuum tubes.

2. Question. Have you read the depositions of plaintiff's witness, Frank M. Waterman in this case?

Answer. I have.

3. Question. Have you read the record which was produced by Mr. Waterman in his answer to Question 9 of his second deposition and marked for identification in this case?

Answer. I have.

4. Question. Do you find set forth in that record any demonstration or demonstrations which show that the two element valve possesses inherently the same capacity for generating radio waves as is possessed by the three-element device?

Answer. No, I do not. The statement that the two-element valve possesses inherently the same capacity for generating radio waves as is possessed by the three-element device is contrary to thoroughly established scientific facts and it is impossible to make any such demonstration. The two-element valve does not possess inherently the same capacity for generating radio waves as is possessed by the three-element device; in fact, the two-element valve does not possess inherently the capacity for generating radio waves at all. In the demonstrations before Judge Mayer advantage was taken of an obscure, freak, impractical phenomenon in order to demonstrate the alleged inherent capacity of the two-element device for generating radio waves. Even this freak operation of the two-element device is basically different from that of the three-element device. These facts were not presented in the record in the case referred to. On the other hand, testimony was given which was not in accordance with the facts.

The two-element device referred to in the record in question consists of an incandescent filament and cold plate insulated from each other within an evacuted inclosure. The device is physically illustrated in the Edison patent No. 307031, October 21, 1884, Figure 4; and also in the Fleming patent No. 803684, November 7, 1905.

[fol. 494] It is a unilateral conductor; that is, it conducts only in one direction. Thus it can be used as a rectifier or as a detector of radio waves. Normally the device is incapable of generating radio waves. If the exhaustion of the

bulb is not complete so that a definite amount of gas is left in the inclosure, it is possible by reason of the action of this residual gas to obtain oscillations with some two-electrode tubes. In order to obtain this freak behavior, it is also necessary to operate the filament at a high degree of incandescence and to impress a high and critical value of voltage between the plate and filament electrodes of the tube. The operation takes place on the critical border line, beyond which the gas renders the device inoperative for all purposes. The requirements for this freak operation are such as to be destructive of the device itself. Such oscillations as are obtained are unsteady and unreliable, so that the phenomenon is incapable of practical use and is of no utility whatsoever.

If the two-electrode tube is to have any capacity at all for generating radio oscillations there must be a considerable amount of residual gas left in the bulb or must be what is known as a "soft" tube. A high vacuum or "hard" two-element device can not generate radio waves. It will, however, operate as a rectifier or radio detector. The two-element device can only operate as a generator by reason of the residual gas, by reason of what is known as "gas ionization." This critical, worthless operation of the two-electrode tube is not a proof of its inherent capacity for generating radio waves.

Even this freak operation of the two-electrode tube in generating radio waves is basically different from the operation of the three-electrode tube, so that the statement is absolutely untrue that the two-electrode tube has the same capacity for generating radio waves as is possessed by the three-electrode tube.

The three-element device referred to in the record before Judge Mayer is illustrated in the De Forest patent 879532, February 18, 1909. It comprises an incandescent filament, a plate, and another electrode usually grid-like in structure which may be interprosed between the filament and plate inside of an evacuated inclosure. It operates as a reliable generator, whether or not gas is present in the tube and irrespective of how high the vacuum is made in the vessel. For purposes of comparison, I produce a drawing which I mark "Miller Drawing A" in which in Figure 1, I have copied Figure 4 of the Edison patent showing the two-element valve, and in Figure 2 I have copied that portion of

Figure 1 of the De Forest patent which shows the three-element device.

Three electrode vacuum tubes will operate as generators if the vacuum is the highest attainable with modern methods of exhaust; in such case the residual gas is one hundred thousandth to a millionth of the amount which is requisite for the generation of oscillations with the two-electrode tube. This fact alone proves that the two devices do not possess the same capacity for generating radio waves and that the basic mode of operation is different.

Even taking the case of a three-electrode tube which does have a considerable amount of residual gas, its basic mode of operation does not depend upon gas. It is a well-known fact that every gas has what is known as an "ionizing potential"; that is, a definite minimum voltage below which the particular gas can not be ionized and therefore can not take part in the conduction through a vacuous space. [fol. 495] The three-electrode tube can be operated as an oscillation generator with applied voltages which are lower than the ionizing potential for any known gas. In this case the operation is completely independent of any gas which might be present in the tube.

The art recognizes two distinct classes of devices which are capable of amplifying or of generating oscillations. One of these classes consists of the so-called "negative characteristic" or "falling characteristic" devices, such as the well-known Poulsen or mercury arcs. When residual gas is present in the two-element valve the device may under certain critical conditions generate oscillations in an uncertain way, due to the falling characteristic of the gas, and hence would come under this class. The other class of amplifiers or generators are of the "amplifying relay" type, such as the mechanical relays and microphone relays used to some extent in telephony. The three-electrode vacuum tube which has replaced these devices in the telephone and wireless telephony field falls under this class. The first of these classes is distinguished by having what is known in the art as a "falling characteristic," and it is by reason of this falling characteristic that they can operate as amplifiers or oscillation generators. The two-electrode vacuum tube does not normally possess this falling characteristic and can not act as an amplifier or oscillation generator. It can only do so under abnormal and critical operating conditions when by reason

of the presence of residual gas left in the bulb it can sometimes be made to have this characteristic and hence be capable of amplifying and oscillating in a worthless manner as a sort of laboratory stunt. The arcs, both the Poulsen and mercury, are commonly known to possess falling characteristics. The former is a well-known and useful generator of radio waves. The basic principle of operation of the two-electrode vacuum tube when generating oscillations by reason of residual gas is identical with that of the arc and the circuit in which it acts as an oscillation generator is identical with the circuit which is used with the arc. This was not pointed out to Judge Mayer. In fact, when Mr. Waterman was asked in cross-examination if the two-electrode device when in an oscillatory condition was acting like an arc, Mr. Waterman answered:

"I do not call that an arc, nor do I call that anything which in any way resembles an arc.

"42. Cross-question. You say that it does not in any way resemble an arc?

"Answer. Yes, that is my understanding of it."

I have repeated many times in my laboratory the demonstration which was made before Judge Mayer and I have investigated the characteristic of the two-electrode vacuum tube which must be obtained in order to make it oscillate. The statement made by Mr. Waterman is not in accordance with the facts, the characteristic which the two-electrode tube must have in order to permit it to act as an oscillation generator is similar to the characteristic of the arc and the mode of operation and circuits of the two devices are entirely similar. The high vacuum two-electrode tube does not have this "falling characteristic" and will not generate oscillations.

The three-electrode vacuum tube operates by reason of the controlling action of the grid. It amplifies or oscillates without residual gas or a falling characteristic. The grid [fol. 496] acts as an electrostatic control over the current flowing between the plate and filament of the tube or what is called the plate current. If the potential of the grid is varied, the plate current varies; if the grid becomes more positive the plate current increases, and vice versa. Thus, if an alternating voltage is applied between the grid and filament of the tube so as to make the potential of the grid vary up and down, the resulting variations of the

plate current will be similar and equivalent to an alternating current superimposed upon the steady plate current which flows when the grid is not acted upon. To produce these potential variations of the grid of the tube requires in general a very small amount of power, but the power represented by the alternating current produced in the plate circuit or the output power can be thousands of times as great. The output power is of the same frequency and wave form as the input power. This is the action of the three-electrode vacuum tube as an amplifier, viz., the output power is an amplified or enlarged reproduction of the input power. It is only necessary in an appropriate circuit to take some of the enlarged output power and feed it back to the input, so that the output itself supplies the input power to make the device operate as a self-generator of alternating currents or an oscillator. This controlling action of the grid is effective no matter how high the vacuum is made; it would still be effective in a perfect vacuum if such were obtainable, and a three-electrode vacuum tube with a perfect vacuum would amplify and oscillate in just the same way as they do in the vacuum which is obtainable in actual practice. Thus I find no demonstration in the record of the case before Judge Mayer which justifies the conclusion that the two-element and three-element devices have the same inherent capacity to generate radio waves and, as a matter of fact, such a conclusion is entirely contrary to well-known and thoroughly established scientific facts.

The above statements are not only my own observations and testimony but are in accord with the accepted views of scientists of the present day. In the recent authoritative work of Dr. H. J. Van Der Bijl, one of the foremost scientists in this field, entitled "The Thermionic Vacuum Tube," I find on page 271, following a mathematical demonstration on the conditions for oscillation of a two-element device, the following:

"From this we see that in order to obtain sustained oscillations from a device having only two electrodes it is necessary that the device shall have a negative resistance. Examples of negative resistances have already been given in the previous pages. Thus, an arc may have a negative resistance, its characteristic being of the form shown by the curve AB in Figure 34. The resistance is given by the

slope of the characteristic and this is a negative quantity for a characteristic of the kind shown. Figure 16, page 48, shows another characteristic which over a region ABC has a negative slope and is obtained as the result of the emission of electrons from metals under the impact of electrons. Such characteristics as these are sometimes referred to as 'falling characteristics.'

"The thermionic valve does not show a falling characteristic like the curve AB of Figure 34, when it is sufficiently well evacuated to prevent the effects of ionization by collision from appreciably influencing the discharge. The characteristics of thermionic valves are those given and discussed in the previous chapters and it will be seen that [fol. 497] for such devices the resistance is always positive. It is, therefore, impossible to obtain sustained oscillations from a well-evacuated thermionic valve containing only two electrodes. If such a device contains an appreciable amount of gas during the operation, the characteristic becomes unsteady and sometimes, especially at the higher voltages, exhibits regions over which the slope is negative, and when operated over that region it is, of course, possible to obtain sustained oscillations. The condition which makes this possible in a two-electrode device is unfortunately due to the cause which makes such a device unsatisfactory, namely, the presence of too much gas in the device, thus causing unsteadiness of the discharge and making reproducibility practically impossible. If a controlling electrode or grid be added to the two electrodes of a valve, the operation becomes different and we now have a device which can produce sustained oscillations with facility while at the same time satisfying all the conditions that are necessary to secure satisfactory operation in every respect, namely, freedom of gas with consequent steadiness and reproducibility of results and comparatively long life."

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Doctor Van Der Bijl distinguishes clearly between the two classes of devices represented by the arc on the one hand and the three-electrode vacuum tube on the other, as I have pointed out, is the practise of the art. Thus on page 108 he states:

"It is the negative resistance of the arc which enables it to produce sustained oscillations. It will be shown in Chap-

ter VIII that a device containing only two electrodes can only produce sustained oscillations if it has a negative resistance or a falling characteristic. The principle involved in the production of sustained oscillations by the audion or three-electrode thermionic tube is entirely different and depends on the controlling action of the grid on the electron flow from filament to anode."

Doctor Eccles, an eminent English authority on radio subjects, performed an experiment before the London Physical Society which was analogous to the demonstration before Judge Mayer. Utilizing a special combination of crystals, he was able to obtain oscillations having an audible frequency. His lecture appears in the proceedings of the London Physical Society, volume 22, page 360, 1910. In explaining the operation of his peculiar crystal contact he discusses the characteristic curve of the device, and states on page 361:

"Along this latter part of the curve increasing current is associated with decreasing electromotive force, an unstable state of affairs."

And on page 361:

"The phenomena resembles that of the electrical arc. The unstable portion of the above curve corresponds in fact to the 'falling characteristic' of the arc."

In his book entitled "Wireless Telegraph and Telephony," page 220 (1917 edition), he states:

[fol. 498] "Like the contact detector and for a similar reason, some samples of the Fleming valve can be arranged to give oscillatory current in a shunt circuit."

Outside of this special crystal contact which Eccles utilized I know of no crystals which have other than a rising characteristic. Crystals are incapable of generating oscillations, though a great number of crystal contacts have been and are being utilized as radio detectors. Similar to the demonstration before Judge Mayer, this experiment of Eccles, which was sufficient of a curiosity to exhibit before a learned society, cannot be taken as a proof that crystal detectors are inherently capable of generating oscillations. Further, Eccles points out that it is the "falling characteristic" of the arc which enabled his peculiar crystal con-

tact and some samples of the Fleming valve or two electrode device to oscillate after a fashion.

The very recent (1921) publication of Bernard Leggett entitled "Wireless Telegraphy" shows that the two-electrode device is not considered to be an amplifier or oscillator. Thus on page 160:

"The Fleming valve was purely and simply a rectifier or detector. In no way was it an intensifying device; it did not use a very high vacuum, as is the case in the modern valves of Langmuir and Meissner, and was not a means of generating oscillations like these later valves."

5. Question. Please examine copies of the patents to Hewitt, 781001 and 781002, and also the copies of opinion in the case of Hewitt *v.* American Telephone & Telegraph Co., reported at 272 Federal Reporter, page 194, a copy of which I show you, compare the operation of the device of the two Hewitt patents with the defendant's device referred to in this opinion, and state to what devices the following statement of Judge Mayer in this opinion referred to:

"It was further proved to my satisfaction that defendant's devices amplify not because of any characteristic of the conducting space as in the Hewitt inventions but because of the use of the De Forest grid."

Answer. The Hewitt patents Nos. 781001 and 781002 relate to the use of inclosed gas or vapor conductors as amplifiers in particular to the use of what is commonly known as the mercury arc. Thus the patents state:

"In the present invention I avail myself of the peculiar features of electrical resistance in a gas or vapor conductor to vary or magnify the effects produced by potential variations in a circuit. By virtue of the described characteristics of gas or vapor conductors it is possible, for instance, to translate variations of potential in a circuit into variations of current or quantity, and inasmuch as the conducting gas or vapor responds practically instantaneously to the applied variations of potential currents of any practical rapidity or frequency can be made to undergo the described transformation and produce their effects upon a suitable receiving apparatus."

As I have pointed out in my previous answer, the characteristic of a mercury arc or other two-electrode device, which is necessary in order to permit it to amplify or generate oscillations is the "falling characteristic." Both the two-electrode valve when capable of amplifying or oscillating and the mercury arc are gas devices and operate by virtue of the arc characteristic.
[fol. 499] A device has a falling characteristic when the potential across its terminals decreases under increase of current.

Relative to the Hewitt device, Doctor Millikan, defendant's expert, testified:

"The condition for amplification in such a circuit is that there be a falling electromotive force current characteristic."

In this opinion Judge Mayer makes the following statement relative to the Hewitt device which is likewise applicable to the two-electrode valve used in the demonstration referred to in my previous answer.

"As the result of this and other testimony I am satisfied that, as contended by defendant in the Hewitt circuit, if amplification results it is entirely due to the device having the characteristic that the potential across its terminals decreases under incre-se of current, and this is the 'peculiar feature of electrical resistance in a gas or vapor conductor' referred to in the specification. Mr. Hogan, plaintiff's expert, in effect, came to the same opinion."

The defendant's device, on the other hand, was the three-electrode vacuum tube, the device with the De Forest grid, as illustrated in my drawing A. Thus the opinion states—

"Defendant's device consists of an evacuated glass vessel with three electrodes sealed in it: (1) The filament heated by an electric current; (2) a grid; (3) a plate. The input circuit is connected with (1) and (2), and the output circuit with (1) and (3)."

"The fundamental principle of operation of defendant's device, according to defendant's contention, is that of a relay."

"Devices of this sort, connected to operate in this manner, are known as 'relay' devices, and a relay in the sense here

used is a device connecting two individually distinct circuits, whereby the signals of one are repeated into the other."

In this later case Judge Mayer was fully informed as to the facts, and the statement to which my attention is called in the question is in accordance with well-known and thoroughly established facts. In this quotation from Judge Mayer's opinion in your question the defendant's device referred to is a hard vacuum three-electrode tube, illustrated in my drawing A, and the Hewitt device is the gaseous two-electrode device.

In other words, the Hewitt inventions referred to in the question are the same thing and oscillate for the same reason as the gaseous two-electrode device demonstrated before Judge Mayer in the record referred to in your Question 3.

* * * * * * *

6. Question. Referring to your drawing A showing the two-element valve and the three-element device, respectively, please explain the fundamental operation of each of these devices.

Answer. The operation of both the Edison two-element valve which is Figure 1 of my drawing A and the three-element De Forest device which is Figure 2 of that drawing [fol. 500] depend upon the peculiar property of a heated filament of emitting what are called electrons or thermions. These electrons are minute negatively charged particles which are shot out from an incandescent filament in enormous numbers per second. The filament of any ordinary incandescent lamp is always emitting these electrons when the lamp is lighted. The mass of these minute particles is about one two-thousandth of that of an atom of hydrogen. In the case of the ordinary incandescent lamp, the electrons shoot out from the filament and after an excursion of greater or less extent return to and enter the filament again. Thus the heated filament is at all times surrounded by a swarm of electrons which are continually being shot out and returning to the filament again.

When a metal plate is sealed in the bulb, in addition to the heated filament as in the Edison tube, the vacuous space between the filament and plate exhibits a unilateral conductivity.

When the plate is made positive with respect to the filament it will exert an attractive force upon the cloud of negatively charged electrons around the filament and a fraction of these will be drawn continually across the space to the plate electrode. These electrons will enter the plate and flow back through the external circuit to the filament again. The convection of these negative charges constitutes an electrical current around the circuit and if a galvanometer is included in the circuit it will indicate a flow of current. The flow of electrons is from the filament to the plate inside the lamp and from the plate back to the filament in the external circuit. It is a flow of negative charges and has the same effect upon the deflection of the galvanometer as would be produced by a motion of positive charges in the opposite direction around the circuit. The direction of current flow has always, by convention, been based upon an assumed motion of positive charges, hence the galvanometer deflection according to the convention would indicate a current flowing from the plate to the filament inside the tube.

If the plate is made negative with respect to the filament, it will tend to repel the negatively charged electrons and hence drive them back into the filament. Thus there will be no flow of current between the plate and filament when the plate is made negative; in fact, in high-vacuum tubes even a hundred thousand volts will not produce an appreciable flow of current in this reverse direction. The device is, therefore, a unilateral conductor, as such it can be used as a rectifier for alternating voltages.

Figure 1 of the sketch which I now produce and mark "Drawing B" illustrates the operation of the Edison two-element valve as a rectifier. The filament F is heated by the battery A. A single circuit connects the plate P and the filament, and in this circuit is a source of alternating voltage and a direct current indicating device I which may be a galvanometer or direct-current ammeter. The alternator voltage makes the plate successively positive and negative with respect to the filament. When the plate is made positive, electrons are attracted to it and flow across the space from the filament to the plate. They enter the plate and return through the external circuit, the indicating device, and the alternator to the filament again. When the alternator voltage makes the plate negative, the electrons are repelled rather than attracted, so that there is no motion of charges through the space between the filament to the plate. There

[fol. 501] is no flow of electricity in the circuit during this interval. Hence a pulse of current flows around the circuit during the alternation of the voltage which makes the plate positive, and these pulses are all in the same direction. Between these pulses or during the negative alternation, the current is zero. The lower part of Figure 1 shows these pulses of current; the base line represents zero current. Such a succession of unidirectional pulses constitute a direct current and will affect a direct current galvanometer, the galvanometer after a fashion averages these pulses and indicates a deflection which corresponds to the average rate of transfer of electricity in the circuit. Thus the action of an alternating voltage upon the two-element valve is to produce a flow of direct current which can actuate a direct current instrument. The two-element device is, therefore, a rectifier.

The three-electrode device of De Forest, which is Figure 2 of drawing A, is an amplifying relay or amplifier. The function of such a device is to magnify alternating current power. When stimulated by an alternating voltage, the device should take little or no power from the voltage source, but should put out an alternating current of exactly the same form as the stimulating voltage and which represents a very much greater amount of alternating current power. Thus the function of an amplifier is to keep the character of the alternating quantities unchanged but to increase their power. This is quite the opposite from the function of a rectifier which is required to change the character, viz., convert from alternating current to direct current and in which the power is all supplied by the source.

The operation of the three-element tube is shown in my Figure 2 of drawing B. In addition to the filament F and plate P of the Edison device, there is a grid G, which as its name implies, is usually a grid of wires interposed between the filament and plate. This device has always two distinct circuits, one connecting the grid and filament in which the stimulating alternating voltage is impressed or the input circuit and the other connecting the plate and filament which is the output circuit and contains the device T which in this case must be responsive to the same frequency as is supplied by the input generator. The operation of the three-element tube requires the insertion of a battery B or a direct current generator in this output circuit. This battery has a voltage of roughly twenty to a hundred volts for low-power

tubes but may be as high as ten or fifteen thousand volts for high-power tubes. The battery is poled so that a positive voltage is always applied to the plate of the tube. Thus the electrons which are being emitted by the filament are always being attracted over to the plate. They pass between the grid wires on their way to the plate. Thus a current called the plate current is always flowing between filament and plate inside the tube and back again through the external circuit. In the grid circuit there is either no battery as shown in the figure, or if any battery is used in this circuit it is poled so as to make the grid somewhat negative with respect to the filament. A flow of electrons to the grid is not desired in this amplifying device; in fact, if any such flow were to here take place it would reduce the efficiency of the device as an amplifier or completely destroy its functioning as such. While the grid does not share in the electron flow through the vacuous space, it can control the flow which is taking place between the filament and plate. A mere [fol. 502] variation of the potential of the grid serves to control the flow of electrons to the plate. Thus if the grid is made more negative, the flow to the plate is reduced; if it is made less negative, the plate current increases. Even with a positive voltage of several thousand volts applied to the plate of the tube, a few hundred volts negative voltage applied to the grid can cut off the flow of current to the plate completely. This controlling action of the grid results from the screening effect which it exerts on the attractive force due to the plate. When the grid of the tube is negative, the attractive force of the plate is exerted primarily on the grid itself and does not get through the wires to the cloud of electrons around the filament. The so-called "lines of force" from the plate terminate largely on the grid itself. When the grid is made less negative, fewer lines of force terminate on the grid and a greater number get through and act on the electron cloud around the filament causing an increase in the electron flow to the plate. This screening action of a grid of wires on electrical forces was recognized and treated mathematically by James Clerk Maxwell many years ago and is given on page 310 of volume 1 of his classic work electricity and magnetism. I have applied the results of Maxwell to the case of the three electrode vacuum tube, and I have shown how the constants of such a tube depend upon the structural dimensions. Thus it is made possible to design, on paper, a tube which is to

have definite values of its electrical constants and hence operate in a definite predetermined manner.

These results of mine are given in a paper entitled "The dependence of the amplification constant and internal plate circuit resistance of a three-electrode vacuum tube upon the structural dimensions, published in the Proceedings of the Institute of Radio Engineers, volume 8, page 64, 1920.

When an alternating voltage is impressed between the grid and filament of the tube, as represented in Figure 2 of my drawing B, the potential of the grid varies up and down in accordance with the impressed voltage. The plate current in the tube will vary up and down in a similar manner as illustrated by the wavy line in the lower part of Figure 2. The dash line represents the undisturbed value of the plate current, the base line corresponding to zero current. The variations in the plate current are symmetrical on either side of the dash line and are an exact reproduction of the voltage variations applied to the grid of the tube. This varying plate current is identical with what is obtained when an alternating current is superimposed upon a direct current, and in fact the alternating and direct current components of the plate current can be separated out. The direct current component is the same as the undisturbed plate current and is of little interest. The alternating component, however, represents the useful output of the amplifier.

Since, as I have pointed out, no appreciable flow of electrons takes place in the grid circuit, the alternator in that circuit does not furnish any current, it merely varies the electrostatic potential of the grid. It is therefore running "light" and is supplying practically no power at all. On the other hand, the alternating component of the current in the output circuit represents a considerable amount of power which can be utilized as desired. The device can [fol. 503] actually proach the condition of being an infinite amplifier of power, viz., a finite alternating current power output for a zero alternating current power input. This does not violate the principle of conservation of energy, for the output alternating current power is supplied by the B battery through the action of the grid. This B battery power is, however, cheap and readily available, while the input voltage may be the weak but precious signal at the end a long telephone line which we want to preserve and strengthen.

This explains the remarkable amplifying property of the three electrode vacuum tube which is due to the De Forest grid and which is responsible for the important position of the device in the electrical art.

7. Question. Is the operation of either of these bulbs changed in any way when operated by high frequency currents from what the operation is when operated by low frequency?

Answer. If both of the devices have a high vacuum there will be no difference in their operation whether operated with low or high frequencies. Thus the alternators in my drawing B could have a frequency as is used in ordinary power installations such as 60 cycles per second or frequencies of the order of those important in wire telephony say 800 cycles per second or frequencies such as enter into radio telegraphy and telephony, fifteen thousand to several million per second and the two-element valve would act as a rectifier, the three electrode device as an amplifier in just the same way and with equal facility in each case. The electrons which represent the moving parts in these devices are, as I have pointed out, extremely light; roughly, an atom of hydrogen which is the lightest atom of matter weighs two thousand times as much as an electron. Thus the moving parts have almost no inertia and both devices operate with the same facility whether the frequency be one per second or fifty million per second. It is true that when either of the devices is so "soft" that the residual gas affects the operation appreciably, these gas effects can depend somewhat upon the frequency. Here we are concerned with charged atoms of matter and in some cases the inertia of these relatively heavy atoms can be appreciable at high frequencies. This is true of gaseous devices in general. It is well known that the Poulsen arc does not operate at high radio frequencies in the same manner that it operates at the lower frequencies. Similarly in the case of the two electrode valve generating oscillations by reason of the action of the residual gas as demonstrated before Judge Mayer, I have not been able to obtain oscillations with this device at high radio frequencies while the three electrode high vacuum tube operates readily at these high frequencies. In fact the three electrode tubes have been used to generate oscillations having a frequency of a hundred million per second.

It is recognized as an obvious fact that devices which

depend upon electronic conduction will operate the same regardless of the frequency.

Thus I note that in the record of the case of Marconi Wireless Telegraph Co. *v.* De Forest, et al. on the Fleming patent (263 F. R. 942) the plaintiff itself offered the Electrical World article of December 12, 1914, explaining the operation of the three electrode device, and called as a witness Edwin H. Armstrong, the author of the article, who [fol. 504] testified that the operation described in the article was based upon experimental investigations conducted at low frequencies, and that—

"Xq. 73. You think then that with electrons in a vacuum there would be no reason for supposing that there would be any different action whether you were working with high frequency; that is to say, radio frequencies or low frequency?

"A. No difference at all.

"Xq. 74. Can you give some brief explanation of why you and other scientists make this assumption that in devices of the vacuum type using electron discharges they would operate under both high and low frequencies in exactly the same way, other conditions being equal?

"A. The mass of the electron is so very small, and the speed so enormously high, that the device is practically without inertia and we would expect for all frequencies within reason, or certainly all frequencies such as used in radio telegraphy, the operation would be the same."

* * * * * *

8. Question. Explain the uses of the two-element valve and the three-electrode vacuum tube in connection with radio signalling?

Answer. The two element valve can only be used as a rectifier at either radio or audio frequency, or as a radio detector in which latter case it is also acting as a rectifier.

The three element device may be used as—

(*a*) An amplifier, at either radio or audio frequency.

(*b*) A combined amplifier and radio frequency detector.

(*c*) An oscillation generator.

(*d*) A combined oscillation generator and radio frequency detector.

Exclusive of the freak gas action which I have discussed before and which is of no practical utility and has never

been used in practice, the two-element valve can only operate as a rectifier or as a detector of radio waves in which case it is, as stated, also rectifying. Even as a detector it is inferior to other available detectors and has had little use in the art. The requirements of a device called a "detector" in the radio art arises from the employment of the very high frequencies which are essential for the effective propagation of radio waves. The currents which flow in the transmitting antenna are high in frequency, the electromagnetic waves which these currents produce and which travel out in all directions have this same frequency.

When these waves impinge upon a receiving antenna they set up feeble currents of like high frequency. The art has instruments which will indicate when there is a flow of high frequency current through them, such as the hot wire and thermo-couple ammeters, but the most sensitive of these instruments is relatively insensitive as compared with the instruments available for the indication of frequencies in the audible range or of direct current. Thus it is difficult to obtain indications with the thermal high frequency meter [fol 505] for much less than a thousandth of an ampere. On the other hand, an audible signal is obtained with good telephone receivers when the current through them is a hundred millionth of an ampere and the frequency of the current is 800 or 1,000 cycles per second. Direct current galvanometers are likewise extremely sensitive and will respond to approximately a billionth of an ampere of direct current. It is obvious therefore that a device which can convert the radio-frequency currents over into currents of audible frequency or into direct current is of great importance in radio signaling. The device which produces this conversion is known in the art as a "detector." Thus Eccles, in the glossary of his Wireless Telegraphy and Telephony, defines a detector as—

"Detector: A receiving instrument for converting high frequency current or voltage into a form of current or voltage capable of affecting an indicating instrument such as a galvanometer or telephone receiver."

Without discussing the operation of the various detectors employed in the radio art, I will enumerate the various important types and indicate their importance: The coherer, the magnetic detector, the electrolytic detector, the crystal detector, and the vacuum tube detector.

The coherer was the original detector in wireless. It was very insensitive and only of historical importance. The magnetic detector while rather insensitive was very reliable in operation and has had a moderate use up until recent years. The electrolytic detector was quite sensitive and at one time appeared to be destined for wide use. The chief objection to this type was its liability to be put out of action permanently by strong signals or atmospheric disturbances. The crystal detector in many forms superseded the electrolytic and all other types. It has held the first place for extensive use, and even to-day is widely used.

The vacuum tube detector in the two element form is said to have had a limited use some years ago. Personally, although I have examined and become familiar with many types of American and foreign commercial radio receivers utilizing various types of detectors during the last ten years, I have never seen a commercial radio receiving equipment adapted to utilize the two element tube as a detector and in fact the only specimens of commercial two element vacuum tube detectors that I have ever seen in the past were in a vacuum tube museum at the Washington Navy Yard. On the other hand, I have been familiar with many types of receiving equipment utilizing the three-electrode vacuum tube as a detector and have tested or used thousands of these tubes of perhaps fifty different types. The three element tube has been used extensively for a number of years and at present is being manufactured at the rate of many thousands per day.

Some forms of crystal detectors such as the carborundum detector are very stable in operation but are relatively insensitive; the two-element valve compares in sensitiveness with these detectors but is less convenient because of the requirement of a battery to heat the filament. The more sensitive crystal detectors such as the galena and "perikon" usually require a rather delicate contact and several preliminary adjustments to find a sensitive point of contact, are liable to require readjustment if jarred or if sub-
[fol. 506] jected to severe electrical shocks such as atmospherics or static. These objectionable features are not, however, serious enough to prevent their use by close to a hundred thousand novices to-day. These crystal detectors are sensitive and cheap and use, in general, no batteries. In sensitiveness they even compare favorably with the three electrode vacuum tube when the latter is used in the

old circuits which did not fully utilize the amplifying property of the tube. In the more modern circuits a single three-electrode tube can give a response which is perhaps twenty or thirty times greater than that of the best crystal detector. Excepting for this high sensitiveness which arises solely from the amplifying capability of the three-electrode tube, I am confident that the crystal detector would not have been replaced to any extent as a detector by the three-electrode vacuum tube.

The telephone has been and is almost universally used as the indicator in the reception of radio signals. Thus the conversion of frequency, which is the function of the detector to perform, is from the high radio frequencies to audible frequencies or so-called audio frequencies.

In order for this conversion to take place the radio-frequency oscillations impressed upon the detector must be "modulated" at audio frequency. By this is meant that the amplitude of the high frequency oscillations must be varying at an audio frequency rate. Figure 1 of my drawing C which I now offer, illustrates a radio frequency oscillation which is not modulated. This is what is known in the art as a "continuous wave" or C. W. The amplitude of the oscillations is constant; it differs only from ordinary alternating current in that the frequency may be a million per second. Figure 2 illustrates a so-called "sinusoidally modalated wave." The dotted sine curves show how the amplitude of the oscillations rises and falls. If this variation occurs at a high enough rate so that the oscillations reach a maximum or minimum value, say eight hundred or one thousand times per second, then the oscillations are modulated at an audio frequency. Figure 3 shows the type of modulated wave used in radio telephony, the dotted lines or envelope showing again the variation in amplitude. Either dotted line is the same curve as would represent the variations in current in a microphone transmitter circuit when the vowel "a" (as in father) is spoken into the transmitter. In order to transmit this sound by radio, the high-frequency oscillations in the transmitting antenna must be varied in amplitude or modulated so that the envelope has this form. Figure 4 shows another type of modulated high-frequency oscillations which is characteristic of the spark transmitters used in radiotelegraphy. Each spark discharge of the transmitter sets up a group of high-frequency oscillations in the transmitting antenna. Figure

4 shows two of these groups or "wave trains." If these sparks occur, as is customary, at the rate of about 1,000 per second, there will be a thousand of these wave trains set up per second. Thus the amplitude of the oscillations rises to a maximum and falls again to zero at an audio-frequency rate or the oscillations are modulated at an audio-frequency rate.

The form of the oscillations in the receiving antenna will be in each case a duplicate of the oscillations in the transmitting antenna. But none of the types of oscillations shown in my figure can affect directly either a galvanometer [fol. 507] or telephone receiver. For the amplitude of the high-frequency oscillations is at each instant the same in both the positive and negative directions and the average current is zero for an interval of time longer than the period of the high-frequency oscillation. The action of the detector is to suppress the amplitude of oscillation in one direction; that is, to cause a distortion of the symmetry of the oscillation. In the case of a perfect rectifier, the oscillations in one direction are completely suppressed. We may consider such an action to wipe out completely the portions of the oscillations below the center line in all of the figures. As discussed in a previous answer, the oscillations of Figure 1 then are converted into a succession of unidirectional pulses of current following each other at a rate of say, a million a second. The average of these is a direct current which will affect a galvanometer but would not produce a sound in a telephone receiver. The oscillations of Figure 2 likewise become a succession of unidirectional pulses; however, these pulses are not equal in magnitude but increase and decrease at an audi--frequency rate. This is equivalent to a direct current which is varying at an audio-frequency rate; in fact the upper dotted sine curve represents the form of this varying current. This is the equivalent of an audio-frequency alternating current superimposed upon a direct current. If a galvanometer were used as an indicator, its deflection would correspond to the direct current component; a telephone receiver responds only to the alternating current component. If the original oscillation were modulated, as we assumed, at a frequency of 800 or 1,000 cycles, then the telephone receiver will respond to the rectified oscillations giving out an 800 or 1,000 frequency note. The case of Figure 1 and Figure 2 show wherein modulation at an audio-frequency is required for

telephonic reception which is the method employed almost universally.

When the oscillations of Figure 3 are rectified the varying direct current will likewise have a form similar to the upper dash line. A telephone receiver will respond to only the varying component, which, as was pointed out before, is the form of the microphone transmitter current corresponding to the vowel "a." The response in the telephone will therefore be the vowel "a."

The rectified pulses of current of Figure 4 will again produce a varying current following in from the upper dash line of that figure. The varying component of this, while not a pure sine wave, has a frequency of 1,000 cycles per second, if, as assumed, the sparks at the radio transmitter occur at a frequency of 1,000. The note in the telephone receiver will therefore correspond to the spark frequency of the radio transmitter.

Summarizing thus far, the action of a detector is to convert from radio-frequencies to direct current or audio-frequency current. The latter conversion can only be effected when the radio-frequency oscillations are modulated as in Figures 2 to 4.

Oscillations of the type of Figure 1 are largely used in radio telegraphy and, in fact, are displacing the spark type of Figure 4. These continuous oscillations are also received with telephone receivers by a method known as "beat note" reception. This consists essentially in producing a modulation of the high-frequency oscillations at the receiver instead of at the transmitter. For this purpose a radio-frequency oscillation generator is required at [fol. 598] the receiving station. The frequency of this local oscillator is made slightly different from that of the incoming oscillations and the two sets of oscillations are superimposed. The resultant oscillation is similar to that of Figure 2 and when this is acted upon by a detector there results a note in the telephones.

In general, the detector is not a perfect rectifier and the oscillations in one direction are not completely suppressed but distorted. The mode of operation is, however, not materially different from that explained above. The distorting action of the various types of detectors is similar whether it be a crystal detector, magnetic detector, two-electrode valve or three-electrode vacuum tube. The latter, however, possesses the important function of amplifying

which is not possessed by the other types. This amplifying action may take place simultaneously with the distorting action, in which case the device is called a detector, or some other detector can be used to produce the distortion and the three-electrode vacuum tube used as an amplifier pure and simple. It is this amplifying property which is responsible for the revolution in the radio art brought about by the three-electrode vacuum tube. The latter tube is used as an amplifier of both audio and radio frequency currents or voltages. Suppose that the signals from a distant station, when converted by the detector to audio frequency, produce currents too feeble to cause an audible response in the telephone receivers. Doubtless if telephone receivers were available having five hundred or a thousand times greater sensitiveness, the signals would be audible. The use of the three-electrode vacuum tube as an audio-frequency amplifier permits this result to be obtained. For the weak audio-frequency currents can be applied through a transformer to the input of a three-electrode vacuum tube. They are then magnified and if the telephone receivers are inserted in the output circuit of the tube, the current through the telephone receivers will be twenty to fifty times as great as those obtained without amplification. Or these currents which have been magnified twenty to fifty times can be applied through a transformer to a second vacuum tube and the current in the telephones multiplied again by twenty to fifty times, a resultant magnification of four hundred to twenty-five hundred fold. An apparatus which thus combines transformers and three-electrode vacuum tubes is called an audio-frequency amplifier. Such an amplifier with the telephone receivers constitutes an audio-frequency indicating device of extreme sensitiveness. It is to be noted that its function is entirely different from that of the detecting device. The latter distorts radio-frequency currents and converts them into audio-frequency currents, the former magnifies and preserves audio-frequency currents. Audio-frequency amplifiers are built and sold in large numbers to the public and have been used extensively by the Government. They may be used in radio signalling with any type of detector, amplifying the audio currents supplied by the detector. Or they may be applied to uses entirely separate from radio signaling. For example, during the war both the French and American armies employed such

amplifiers extensively in what was called T. P. S. signaling which utilized audio-frequency currents transmitted through the ground. The use of similar audio-frequency amplifiers employing three-electrode vacuum tubes makes possible long-distance wire telephony.

[fol. 509] Of late years the use of the three-electrode vacuum tube as a radio-frequency amplifier has become of increasing importance. In this use the weak radio-frequency currents which constitute the received signal are magnified before they are applied to the detector and converted into audio frequencies. Such an amplifier usually consists of three-electrode vacuum tubes and transformers, each tube magnifying the radio-frequency output of the tube ahead. The radio-frequency voltage may by successive stages of amplification be increased thousands of times before being applied to the detector. The importance of such results in radio signaling is obvious.

Quite frequently both types of amplification have been utilized in one instrument, called a radio-audio-frequency amplifier. Thus three tubes may be used to amplify at radio frequencies; the output is applied to the detector and then amplified again at audio frequencies through perhaps two tubes more. For convenience the detector is usually a three-electrode tube also though in numerous instances the crystal detector performs the detecting function. With such an instrument radio signals from Europe can be received in America using a small coil indoors for a receiving device instead of the usual outdoor antenna.

As I have pointed out, when the three-electrode vacuum tube is used as a detector, the amplifying action is also going on simultaneously. It may be the equivalent of a detector and audio-frequency amplifier or radio-frequency amplifier and detector depending upon the circuit utilized. In one circuit the distortion is produced in the input circuit of the tube and the resulting audio frequency is amplified into the output circuit. In another circuit the radio frequency is first amplified into the output circuit and is there distorted into audio frequency. That the detecting action is very inefficient as is the case with the two-element valve, is proven by the fact that the net result of the detection and amplification in simple circuits is very little better than that furnished by a crystal detector which does not amplify at all. As stated before it is only when circuits are employed that enhance many times the amplification

which is secured, that the three-electrode vacuum tube decidedly bests the crystal detector in net results.

By reason of the fact that the three-electrode vacuum tube is a power amplifier, it can be made to act as an oscillation generator. As such it has two important uses in radio signalling.

First, it is an extremely convenient source of local oscillations in "beat note" reception discussed above. It can at the same time supply the local oscillations to modulate the received continuous wave signals and also serve to distort the resultant modulated oscillations into audio frequency thus acting simultaneously as a generator and detector, or with equal results a crystal can be employed as the detector, the three-electrode tube functioning solely as an oscillator.

Second, the three-electrode tube can be utilized as an oscillation generator to supply the radio-frequency currents to the transmitting antenna. In this respect it has a number of advantages over other available generators of radio-frequency currents. It is very flexible and readily generates frequencies as high as a million per second. Its competitors, the alternator and arc are not capable of generating such high frequencies. Further the output current of vacuum-tube generators is easily controlled and thus the tubes are particularly valuable for radiotelephony. [fol. 510] At present, single tubes of the three-electrode type have been produced which are capable of supplying 5, 10, or 25 kilowatts of radio-frequency power to transmitting antennas and the available power can be further multiplied by operating the tubes in parallel.

Another important use of three-electrode vacuum tubes is that of acting as "modulators" in radiotelephony. The oscillating vacuum tube supplies continuous waves to the antenna as illustrated in Figure 1, drawing C. In order to transmit telephony, these oscillations must be modulated so that the envelope of the oscillations is a reproduction of the current variations produced by the voice in the microphone transmitter as in Figure 3, drawing C. With very low power vacuum-tube oscillators, this modulation can be effected by the microphone itself. This requires, however, that a certain percentage of the total power be supplied by the microphone. This instrument is capable of supplying only a very small amount of power, so that, the micro-

phone itself can not modulate high-power tubes effectively. Hence a three-electrode vacuum tube is employed to amplify the audio frequency output of the microphone and this amplified output is employed to modulate the oscillations produced by the generator tube. In the case of very high-power tubes, two stages of amplification may be required before sufficient audio-frequency power is produced. The action of the so-called "modulator tube" in wireless telephony is therefore simply action as an audio-frequency amplifier.

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9. Question. Explain what is meant by the characteristic curve of a device, what is meant by a "rising" or "falling" characteristic and what the various types of characteristics indicate?

Answer. The characteristic curve of a device or a conductor is a graph or plotted curve showing the relation between the current through the device and the voltage applied to it. Such a curve is obtained simply by applying various voltages to the device and noting the current which flows through it for each voltage value. Points are then plotted for each pair of corresponding values of voltage and current and a smooth curve drawn through the plotted points. Since the opposing voltage offered by the device is always equal to the applied voltage, the characteristic curve can also be regarded as a graph of the opposing voltage offered by the device for different values of current flowing through it. Figure 1 of my drawing D which I now produce illustrates the characteristic curve of an ordinary resistance such as a wire coil. Such conductors are said to obey Ohm's law, that is, the current is proportional to the voltage. The characteristic curve is for this reason a straight line. Figure 1 represents the characteristic curve of such a coil having a resistance of two ohms. When a voltage of 2 volts is applied to this coil the current will be 1 ampere. This is denoted by point A on the curve. When the voltage is raised to 4 volts the current will be 2 amperes, denoted by point B. If this latter voltage [fol. 511] be reversed the current will also be reversed but will still have a value of 2 amperes. The voltage and current are then considered to be negative and correspond to point C on the curve. If an alternator giving a sine wave alternating voltage having a maximum value of, say,

4 volts is applied to this resistance, the current during a cycle will increase from zero as the voltage increases from zero reaching the point B when the voltage is at its maximum value in the positive direction. As the voltage falls to zero again the current will likewise decrease to zero. The voltage will then reverse and increase in the negative direction. The current wi'' also flow in the reverse direction increasing with the voltage until the point C is reached corresponding to the maximum value of the voltage in the negative direction. Since the current flows in the direction of the alternator voltage and is always proportional to it, the wave form of the current will be a sine curve identical with that of the voltage. While the alternator voltage is, at each instant, in the same direction as the current flow, the opposing voltage offered by the resistance is in the opposite direction to the current. The alternator is supplying the power, the resistance is absorbing the power. We have here a criterion as to whether a device is a generator of alternating current power or absorbs such power. If the variations in voltage across a device are in the same sense or direction as the variations in current through the device, then it is a generator of power; if the variations in voltage across the device are in opposition to the variations in current through it, then it is an absorber of power. In Figure 1 I have introduced the letters, N, S, E, and W, to indicate the directions of the compass, as on a map. The characteristic curve of the resistance at all points runs in the general direction of NE to SW or vice versa.

If I had assumed a higher value of resistance the curve would run more nearly E and W for a given current would cause a greater opposing voltage or voltage drop. If the resistance were infinite then the current would be zero for all voltages and the curve would run E and W. For low values of resistance, the curve would run more nearly N and S approaching that direction as the resistance approaches zero. Thus the curves of all ordinary resistances run in the general direction of SW. to NE. Any conductor which has a characteristic curve that runs at all points in this general direction will exhibit the same behavior as a resistance with regard to the sense or direction in which the opposing voltage varies with varying current. Hence, any device of this type must be a power absorber. Such a characteristic curve is said to be a

"rising characteristic." I shall show later that there are some conductors possessing a characteristic which throughout or at some portion runs in the general direction of SE. to NW. These devices are said to possess a "falling characteristic" and in virtue of this characteristic can function as amplifiers or oscillation generators. In devices having a rising characteristic, increasing current is associated with an increasing voltage drop, or vice versa. The characteristic is also said to have a positive slope. The falling characteristic entails an increasing current associated with a decreasing voltage drop or vice versa. In this case the characteristic is said to have a negative slope.

In the case of such devices as have a falling characteristic or negative slope, when the current through the device increases, the opposing voltage decreases, when the current decreases the opposing voltage increases. This action [fol. 512] assists the changes in current and is just the opposite of the behavior of an ordinary or positive resistance. On this account these devices are sometimes said to act as "negative resistances." In reality they act as alternators, when the current through them is an alternating current, they supply an alternating voltage which assists the flow of alternating current. Suppose, for example, that an alternator is supplying current to a long line of high resistance and one of these "failing characteristic" devices is inserted in the line. As the alternator tends to force current through the line in one direction the voltage drop across the resistance increases and opposes the flow of current. The voltage drop across the falling characteristic device, however, changes in the opposite direction and counterbalances to a greater or less degree the opposition offered by the resistance of the line. For a given change in current the net opposing voltage is reduced or the line behaves as if its resistance were lowered. Thus a given alternator voltage will produce a greater alternating current in the line. If, for example, the alternator were a microphone transmitter operating into a long telephone line, the speech currents in the distant receiver would be increased by the insertion of such a falling characteristic device in series in the line. Thus such a device can act as an amplifier. For stability to obtain in an electrical circuit, the opposing voltage must at each instant be equal and opposite to the impressed voltage in the circuit just as action and reaction counter-

balance each other in mechanics. Thus stability requires that the opposing voltage due to the positive resistance be somewhat greater than the assisting voltage produced by the falling characteristic device. The less this margin becomes, the greater becomes the alternating current produced by a given impressed voltage; theoretically when the margin is reduced to zero, no matter how small is the impressed voltage, it will produce an infinite alternating current in the circuit. This result is, of course, impossible, but represents the condition under which a falling characteristic device such as an arc can self-generate oscillations. Suppose that we have a circuit of inductances and capacities which has a certain natural period of oscillation and a negative resistance device is included in the circuit. Suppose that the characteristic of this device is such and the positive resistance of the circuit has a value such that an alternating current of a frequency corresponding to the natural period of the circuit will produce a greater assisting voltage than opposing voltage. The disturbance produced by closing the circuit, or otherwise, will originate a minute electrical oscillation in the circuit, the voltage assisting this oscillation will exceed the opposing voltage and the oscillation will grow, theoretically without limit. Actually the oscillation will grow up to a limiting value determined by the limitations of the falling characteristic device and will continue indefinitely at this limiting value. It is in this way that such a device operates as a self-generator of oscillations or alternating current. A device having two terminals and not having an auxiliary controlling means or member so as to put it in the relay class, must have a falling characteristic in order to operate as an amplifier or oscillation generator. The possession of a falling characteristic is, however, not conclusive evidence that the device can self-generate oscillations of a high frequency. In order to determine this point it is necessary to know something of the mechanism which pro-[fol. 513] duces the falling characteristic, viz, as to its inertia, time lag, etc. Thus there are cases where a device can have a falling characteristic which results from thermal changes in a filament or from slow changes in the character of the surface of a filament. A falling characteristic will be observed when the characteristic curve is obtained experimentally by slow methods which permit plenty of time for the changes to take place but the device for very

rapid changes would not possess a falling characteristic and could not operate as a high frequency amplifier or oscillator.

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In Figure 2, I show the characteristic curve of a carborundum detector. This curve is taken from Figure 238, page 304, of The Principles Underlying Radio Communication, a Signal Corps, United States Army (1918) publication. It will be noted that this characteristic curve differs from the straight line curve typical of the ordinary conductors that obey Ohm's law. It is, however, a rising characteristic throughout.

It is the fact that the characteristic curve deviates from a straight line or has curvature that permits the carborundum crystal to act as a radio detector. We have seen that the application of a sine wave voltage to an ordinary resistance results in a current which is of the same wave form as the applied voltage. This would not be the case for a carborundum crystal. Referring to the figure, it is observed that an application of 20 volts to the crystal in one direction results in a current of more than 800 microamperes, while a reversal of this voltage causes only some 20 microamperes to flow in the reverse direction. In other words, such a crystal produces distortion which, as pointed out in my answer to question 8, is the necessary requisite for a device to operate as a radio detector. It is evident, therefore, that there is no connection between the functioning of a detector and an amplifier or oscillation generator. The former requires that the characteristic be curved; the latter that in two-element devices it be a falling characteristic. Thus, as in the case of the carborundum crystal, a device can have a curved characteristic and function as a detector without any possibility of its functioning as an amplifier or oscillation generator. On the other hand, the device can have a falling characteristic and function as an amplifier or oscillation generator without functioning as a detector. If the characteristic be both curved and falling, then both functions are possible.

In Figure 3 is shown the characteristic curve of the two-electrode vacuum tube taken from Figure 244, page 313, of the same publication. This is likewise a curved and also a rising characteristic excepting perhaps for high plate voltages where the curve tends to become horizontal

and approximates the slope of an infinite resistance. For such high plate voltages all of the electrons emitted from the filament are being attracted to the plate as fast as they are being emitted. It is obvious that an increase in the plate voltage can not result in the attraction of any more electrons than the total available number. This is called the "saturation current" of the tube and the filament temperature must be increased and more electrons [fol. 514] emitted from the filament per second in order to obtain a greater current. The dotted curve marked Temp T_2 corresponds to such an increased filament temperature.

Figure 4 taken from Figure 220, page 288, of the same book shows the characteristic of the arc. This is a "falling characteristic" throughout. Descriptive of this curve the 1920 edition of this publication states on page 402, "It is this 'falling characteristic' of the arc that makes possible its use as a generator of undamped oscillations."

Figure 5 is an experimental characteristic curve which I have obtained and which explains the possibility of ob-
tube as in the demonstration before Judge Mayer. The
taining oscillations with a "soft" two-electrode vacuum
region of the curve from O to P has a negative slope or is a "falling characteristic." The rest of the curve is a "rising characteristic." I found that oscillations started with this tube when the voltage on the tube reached the point O. At a somewhat higher voltage the tube went over into a "blue glow" and the oscillations stopped. This blue glow is a well-known accompaniment of gas ionization and shows that the tube was a "soft" tube. The characteristics of the two and three electrode high vacuum tubes are rising characteristics throughout, the two-element tube cannot act as a generator, the three-electrode acts as a generator by reason of the grid control and belongs to another class of devices.

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10. Question. You have referred to the arc as having a falling characteristic and as operating by reason of this characteristic. Is this explanation in accordance with the accepted knowledge of the art?

Answer. It is. Figure 4 of my drawing D is taken from the Signal Corps textbook Principles Underlying Radio Communication, which was written by experts from the

Bureau of Standards in conjunction with a number of eminent professors of physics and electrical engineering from various universities. In Fleming's book, Principles of Electric Wave Telegraphy and Telephony, 1916 edition, is given in Figure 86, page 109 (copy of fig. 86 inserted opposite), experimental characteristic curves for a carbon-carbon arc in air and a copper-carbon arc in hydrogen. These are both falling characteristics, the latter being the steeper. They are representative of the so-called Duddell and Poulsen arcs, respectively, the latter being the type utilized extensively in radio signaling. The accompanying theory on the action of the arc as an oscillation generator points out in numerous places that the important characteristic of the arc is that it has a falling characteristic. The Duddell arc is an open arc in air and was capable of generating only frequencies in the audio range and not capable of generating radio-frequency oscillations, at least to any degree of efficiency. Poulsen, however, introduced modifications which are shown, in the figure referred to, as having changed importantly the characteristic of the arc and Poulsen's modifications made possible the utilization of the arc for radio-frequency current generation.

[fol. 515] On page 108 of Vander Bijl's book, The Thermonic Vacuum Tube, already referred to, he shows in Figure 34 a curve A B which represents the falling characteristic of the arc and compares it with a rising characteristic O C which is typical of hard vacuum tubes. The text states:

"Since the slope of the curve A B is negative, the arc has a negative resistance, while the resistance of a gas-free tube is positive.

"It is the negative resistance of the arc which enables it to produce sustained oscillations. It will be shown in Chapter VIII that a device containing two electrodes can only produce sustained oscillations if it has a negative resistance or a falling characteristic. The principle involved in the production of sustained oscillations by the audion or three-electrode thermonic tube is entirely different and depends on the controlling action of the grid on the electron flow from filament to anode."

Also in the book, Wireless Telegraphy, by B. Leggett, on page 375, after discussing the Duddell and Poulsen arcs, the statement is made:

"The existence of the oscillation depends upon the fact that the resistance of the arc varies with the current in such a manner that the potential difference between the carbons diminishes with increasing current, and the arc behaves as though it had a negative resistance."

Eccles in the 1918 edition of his Handbook of Wireless Telegraphy and Telephony states on page 215:

"The ability on an arc to sustain oscillations in a shunt circuit depends on the fact that in the circumstances in which it is used, an increase of current through the arc involves a decrease of the voltage at its terminals, and vice versa. The curve connecting i and v with values of i as abscissæ is called the 'characteristic' curve of the arc: it has a negative gradient."

On page 216, Figure 130, he shows the falling characteristic curve (M P M') of the arc.

Eccles uses a different method of plotting the characteristic curve than is usual. Where he plots currents as abscissæ and voltages as ordinated, the usual custom which I have followed is the reverse. The result is the same; that is, it shows increasing current associated with decreasing voltage, and vice versa.

Almost any textbook on radio will furnish a similar explanation as to the action of the arc as depending upon its falling characteristic, so that I could multiply the number of confirming references indefinitely. It is a fact, therefore, that my explanation is in accordance with the accepted knowledge of the art.

11. Question. Refer to the diagram identified by Mr. Waterman in answer to cross-question 51 and explain how the circuits in these diagrams compare with the circuits of the oscillating arc.

Answer. A typical circuit for the oscillating arc is shown in Figure 1 of my drawing E. This is taken from page 98 of Fleming's book, The Principles of Electric Wave Telegraphy and Telephony, 1916 edition. The arc A is an ordinary carbon arc in air. The battery B supplies direct current to the arc through the resistance R. In a shunt circuit to the arc is a condenser C and inductance L. The oscillations produced by the arc flow in the circuit A C L. In Figure 2 of this drawing I show the identical circuit ex-

[fol. 516] cepting that the arc is replaced by a two-electrode vacuum tube marked "V. T." If this tube is a "soft" tube, as used in the demonstrations before Judge Mayer, then it is possible to obtain oscillations as in these demonstrations. I have done this on numerous occasions. The arc circuit shown in Figure 1 is typical of all arc circuits, but specifically relates to the Duddell musical arc, which was described in 1900 by W. Duddell in an article in the London Electrician, published at London, December 21, 1900, pages 310 to 313, inclusive.

In this paper Mr. Duddell derives mathematically the conditions necessary for the arc to self-generate oscillations. This abstract mathematical treatment is just as applicable to the gaseous two-element tube demonstrated before Judge Mayer as it is to the arc. He shows that—

(1) The characteristic must have a negative slope or its must be a falling characteristic.

(2) The negative resistance of the device must be numerically equal to or greater than the positive resistance of the oscillatory circuit.

On page 12 of the record before Judge Mayer Mr. Waterman states:

"The fact that a two-element valve will oscillate has been known to me for several years, and one circuit in which it will oscillate is the ordinary oscillating circuit used with the oscillating arc, which has been known for many years—as early in fact, as the year 1900, which is prior to the date of the Fleming patent in suit."

Thus Mr. Waterman admits that the two-electrode tube generates oscillations in the identical circuit used with the arc, though in his cross-examination he states that "it does not in any way resemble an arc." In fact, both the circuits and basic mode of operation of the two devices are the same.

Both devices will also operate if the resistance R is placed by an impedance or choke coil, or both the resistance and impedance coils may be utilized.

The impedance coil is most generally used with the arc. Also, while my Figures 1 and 2 show the condenser C and inductance L connected in series, both devices will operate

with the condenser and inductance connected in parallel, although the former circuit is the more usual one employed with the arc. The circuit of Figure 3 shows the impedance Z in place of the resistance R and the parallel connection of the condenser C and inductance L. The condenser C is inserted in order to prevent a short circuit of the battery B through the coil L. This circuit is identical with that used in the demonstration before Judge Mayer and shown in defendant's Exhibit B in this case, excepting for the telephone receivers and condenser C_2, which are not essential. I have also utilized the circuit of Figure 3 in generating oscillations with a "soft" two-electrode tube, as in the demonstration before Judge Mayer.

A distinguishing feature of an arc circuit is the use of either a resistance or the impe*n*dance coil such as Z. In each of Mr. Waterman's sketches of the two-electrode tube as a transmitter, the choke coil is utilized excepting in sketches D and F. These sketches, however, show a telephone receiver which is a high impe*n*dance and usually a high resistance also and therefore operates in place of the choke coil Z.

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[fol. 517] 12. Question. What tests have you made to demonstrate the correctness of your testimony to the effect that such oscillations as were obtained before Judge Mayer were due to the gas characteristic?

Answer. I was a witness for the defendant in the Marconi-DeForest case in New York. I entered this case after the demonstration before Judge Mayer and after his opinion was rendered. My testimony was given before the master in February, 1920. Prior to this time I had heard of this demonstration and although I had studied vacuum tubes, expérimented with them for a number of years, and had made several contributions to the knowledge of their operation, I was entirely at a loss to explain how oscillations could be obtained with a two-electrode vacuum tube. This was contrary to well-established scientific principles and to the well-understood mode of operation of such devices for which the laws had been worked out mathematically by such scientists as Child and Langmuir. In fact it is not possible to obtain oscillations with a two-element vacuum tube. It is necessary to add another characteristic, the characteristic of gas, in order to obtain the freak be-

havior which was taken advantage of in the demonstration before Judge Mayer.

Prior to my testimony before the master, I made a careful study of the record in that case in an effort to determine how this demonstration was worked. The clue resulted from the description of tests in the record, the testimony given by Mr. Waterman and my knowledge of the work of Richardson and Buzzoni published in the Philosophical Magazine, volume 32, page 426, 1916, entitled "Experiments with electron currents in different gases —1— mercury vapor."

In the first test described in the record, the tube showed a blue glow while it was generating oscillations. Such a glow results from the ionization of gas. Thus Mr. Waterman testified:

"34. Cross-question. You noticed this blue glow that occurred in this circuit, Mr. Waterman, when it was acting as an oscillator, as a so-called oscillator?

"Answer. There was a trace of blue glow.

"35. Cross-question. What is the explanation of that?

"Answer. It is the incipient state of the ionization which is occurring around the edge of the plate."

In the second test described in the record oscillations were obtained with another tube which did not show a blue glow. Mr. Waterman testified relative to this test:

"188. Question. Will you explain, Mr. Waterman, the demonstration which has just been made?

"Answer. The demonstration is identical with that which was made yesterday, with three exceptions. The alve which is being used is a different valve and one which on account of a higher vacuum or some characteristic that we do not know, does not require the blue glow in order to oscillate."

Now Richardson and Buzzoni studied the flow of current between a heated filament and another electrode in an evacuated inclosure with mercury vapor present to a cer-
[fol. 518] tain degree. They found that in a given range of pressures of the mercury vapor present and under particular values of the external voltage applied upon the tube that they could obtain a critical condition wherein a sudden rise of current through the space was accompanied

with a reduction in the voltage across the space; that is, a falling characteristic. Whether or not a visible glow accompanied this effect depended upon the vapor pressure in the tube. If the vapor pressure was greater than 0.001 millimeter there was always visible glow, but otherwise there was not. In the latter case while the unstable action took place without any visible blue glow, it was accompanied by the production of ultra-violet light.

This corresponds with the tests before Judge Mayer, the vacuum being somewhat higher in the tube tested the second time than in the first, as testified by Mr. Waterman.

Being familiar with the action of an arc as an oscillator, the possibility of obtaining a falling characteristic by reason of gas in a two-electrode tube at once suggested to me the explanation of the demonstration.

I then returned to Washington and attempted to repeat the experiments before Judge Mayer. I wanted a "soft" two-electrode vacuum tube, but this was not available. In fact all of the vacuum tubes used by the Government, both the Navy and Army, were hard vacuum tubes, excepting that in the early days the De Forest audion, a "soft" three-electrode vacuum tube, was employed. The hard tubes had completely displaced the old tube because of the requirement of dependable and stable operation and reasonable operating life, which was not possessed by the soft tubes. I had available one type of two-electrode vacuum tube which was used in connection with the regulation of propeller driven generators in aircraft work, but this also was a high vacuum tube. I then determined to use the old De Forest tube, converting it into a two-electrode tube by connecting the grid and plate electrodes together and using them as one electrode. This is an artifice which is sometimes employed with a three-electrode tube when only the rectifying action of the two-electrode tube is desired. The old De Forest tube was rare at this time, but I managed to borrow four of them for the tests. Later I found that the Signal Corps had a number of them in storage.

I connected up the circuit used before Judge Mayer, which is Figure 3 of my drawing E, and found that by heating the filament of the tube to an abnormal brilliancy and applying a critical voltage to the combined grid plate electrode I could obtain oscillations. At first I could only make two of the tubes oscillate, but later managed to operate all of them. The operation in every case took place

on the ragged edge beyond which the gas became completely ionized and the tube was rendered inoperative for all purposes. The oscillations which were obtained were unsteady, if the tube were left for a time without making readjustments, the oscillations would die out of their own accord. The whole action was typical of the erratic performance of a device in which gas action played a part and which erratic behavior has caused the art to discard soft tubes for commercial work. The operation is destructive of the device itself, for the ionization of the gas produces heavy positively charged ions which, under the action of [fol. 519] the electric field, bombard the filament and literally tear it to pieces. Coupled with the abnormal temperature required, the life of the filament is very short. This freak operation is absolutely worthless from a commercial standpoint. The oscillations furnished by the tube are neither constant in frequency nor in amplitude, and at that the tube requires frequent adjustments of the applied voltages in order to keep it in the oscillatory condition.

In these first tests I observed that the oscillating condition coincided with the unstable behavior of a gas as described by Richardson and Buzzoni.

At the critical point of operation where oscillations commenced the current through the tube increased suddenly, while the voltage across the tube decreased, viz, the device had a falling characteristic like that of the arc.

Lately I have obtained experimental characteristic curves of these devices of which Figure 4 of my drawing D is an example. The difficulty in obtaining such a curve is very great, as can be realized when consideration is taken of the fact that the device is continually changing. This curve shows clearly the falling characteristic portion which permits the freak action.

I also tried to obtain oscillations in the same circuit with the hard two-electrode tube mentioned above. This tube, while not used as a radio detector, is constructed the same way and could be so used. Although I tried various plate voltages up to those which rendered the plate of the tube red-hot and which were many times greater than those applied to the soft tube, and heated the filament to an extreme degree of incandescence, I was unable to obtain any oscillations whatsoever. This is to be expected, for the character-

istics of this tube, which I have investigated with great thoroughness, are rising characteristics throughout.

13. Question. Referring to the testimony of Mr. Waterman concerning the demonstration before the court at which it was claimed that oscillation was obtained, were the conditions of that test such as to indicate the steadiness of the oscillation or the length of its duration?

Answer. In the experiments performed before the court and as described in the record, the methods utilized for showing the existence of oscillations were not methods which would show the variations in the oscillations which were obtained, but would merely show whether or not such oscillations were present.

14. Question. You referred to a test in which the grid of the vacuum tube was connected to the plate, thus making it a two-electrode device. Did you test the same device with the grid disconnected from the plate so that it functioned normally as a three-electrode tube?

Answer. I used the same tube which was utilized in investigating the oscillating effects of the two-electrode tube in such a circuit and with such connections that it operated as a three-electrode tube, in which case the *drig* was disconnected from the plate, operated at substantially filament potential and acted as a control member in the device. With the tube used and operated as a three-electrode tube, I obtained oscillations throughout a wide range of plate voltages impressed upon the tube and of the heating current through the filament. In this case there was nothing critical about the adjustments of either plate voltage or filament [fol. 520] current. Furthermore, the high-frequency current or output current of the device was perfectly steady and the device would operate as an oscillation generator, apparently indefinitely or throughout the life of the tube.

Question 15. How did the presence of gas affect the operation of the tube when it was being operated as a three-electrode device with grid at filament potential?

Answer. The oscillations did not require the presence of a gas. This is proven in the case of this particular tube by the fact that oscillations were obtained on plate voltages so low that it was impossible for these voltages to produce any ionization of any residual gas in the device. It is well known that for any particular gas there is a voltage called the ionization voltage, below which it is impossible to produce ionization in the gas. I operated this three-

electrode tube at voltages below the ionization voltage for any of the known gases.

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16. Question. In your answer to question 12, you state that the operation of a gaseous two-electrode tube as an oscillation generator is worthless from a commercial standpoint. Will you explain this statement further?

Answer. In the present state of the radio art it is impossible to construct tubes to have gas present to a definite degree and to have such tubes exhibit characteristic, depending upon the gas, with any certainty whatsoever. Furthermore, having obtained some tubes which show the desired characteristic, by selection from a great many tubes, these tubes will not show the characteristic permanently, but will throughout their life, show a varying characteristic. In order to make use of this characteristic introduced by the presence of the gas, it is necessary to perform critical adjustments, and the results obtained will vary during the operation of the tube in such a manner as to require continual readjustments of the operating conditions. The unsteadiness and variability of any such device containing gas, and whose operation depends upon gas, is well known to anyone who has investigated the operation of these devices. Further, the critical conditions of adjustment which are required to bring forth these properties in the tube are also the conditions favorable to an early destruction of the tube and short life. In general, it is necessary that the filament should be operated at a very high degree of incandescense. Further, the voltages applying to the device are such as to produce ionization of the residual gas. It is well known that the effect of such ionization is to cause the filament to be bombarded by the heavy positive ions resulting from the ionization and this leads to the destruction of the filament after a relatively short time of operation.

I have pointed out the critical adjustments necessary in order to utilize the possible amplifying or oscillating properties of this device and the necessity for frequent readjustment of these critical conditions. It would be asking too much of the practical wireless operator to require him to [fol. 521] carry on practical operations with a critical device of this kind, even if he were capable of operating it. In the progress of the radio art the striving is always to

simplify and make certain the operations and adjustments of radio apparatus for practical purposes.

The operator's principal function and main concern is to receive messages. Any receiving device which requires a considerable part of his attention would seriously prevent the operator from performing his real duty. It is obviously impossible for an operator to attend to the receiving of messages and at the same time make frequent adjustments of the apparatus by means of which he is receiving those messages.

17. Question. Compare the operation of the two-electrode valve detector in the circuit of the Fleming patent with the operation of the three electrode vacuum tube or audion in the P N circuit of Plaintiff's Exhibit #83 and in the circuit of plaintiff's Exhibit #114.

Answer. In Figure 1 of my drawing F, which I now offer, is shown a simplified diagram of the two-electrode detector in the circuit of the Fleming patent. This figure is similar to Figure 1 of my drawing B, which illustrates the use of the two-electrode device as a rectifier of alternating currents of any frequency whatsoever, excepting that I have replaced the alternator of that figure by the antenna *n* and oscillation transformer *m*, *k*, shown in the Fleming patent. The latter has the same function as the former, viz, the application of an alternating voltage in the valve circuit. In the Fleming use, the frequency of the alternating voltage is a high frequency, as is used in radio transmission. The operation of the valve is the same in both cases; it is to produce rectified currents.

Thus, Fleming states on page 2 of the specification, lines 18 to 27:

"The arrangement described above operates as an electric valve and permits negative electricity to flow from the hot carbon *b* to the metal cylinder *c*, but not in the reverse direction, so that the alternations induced in the coil *k* by the Hertzian waves received by the aerial wire *n* are rectified or transformed into a more or less continuous current capable of actuating the galvanometer *l* by which the signals can be read."

The device is a detector, as I have defined it and as is the accepted terminology of the art, by reason of the fact that it converts or transforms the received high-frequency alter-

nations into direct current. This conversion is effected by a distortion of the high-frequency alternations, the alternations in one direction being permitted to flow while those in the opposite direction are suppressed.

In Figure 2 of my drawing F is a simplified diagram of the P X circuit as used in the reception of radio signals. This diagram is identical in all essentials with plaintiff's Exhibit No. 83. It is similar to Figure 2 of my drawing B, excepting that the alternator of this latter figure is replaced by an antenna and oscillation transformer j^1 j^2, the secondary coil j^2 of which is tuned by a condenser h^1, and, what is of special significance, a small condenser j^3 is inserted in series with the connection to the grid of the tube. To one skilled in the art the presence of this low capacity condenser, commonly called the grid condenser, in this circuit suggests that the three-electrode vacuum tube is intended to operate as a radio detector. It is loosely termed "detector," but actually, as I have pointed out before and will [fol. 522] more fully explain later, the three-electrode tube operates in this circuit simultaneously as a detector and amplifier.

The circuit of Figure 2 of my drawing B, which omits the condenser j^3, is representative of the action of the tube as an amplifier alone. It is true that there are other circuits, which are not detector circuits, in which a condenser is connected in the grid lead; for example, in the circuit of high-power, three-electrode tubes when used for generating oscillations for transmission purposes or in the circuits of direct-coupled amplifiers such as the resistance type amplifier. The purpose of the grid condenser in these circuits is different and the capacity of the condenser need not be small.

The action of the P X circuit is as follows: Suppose, first, that the incoming radio-frequency oscillations in the receiving antenna are of the continuous-wave type; that is, constant in amplitude or unmodulated. Through the intermediary of the oscillation transformer j^1 j^2 a high-frequency voltage is impressed in the secondary coil j^2, and by reason of the tuning of this circuit a greater voltage usually exists across the condenser h^1. This voltage is impressed between the grid G (through condenser j^3) and the filament F of the tube. When the first of these alternations are applied to the tube they produce rectified current pulses between the

grid and filament of the tube, the action being similar in this respect to that of the two-electrode rectifier. These unidirectional pulses consist of a flow of negative electrons from the filament to the grid inside the tube and, as explained before, are the equivalent of a direct current. However, the presence of the small condenser j^3 prevents the lasting flow of direct current in the grid circuit, the current pulses accumulate on this condenser and quickly give it a charge. Since the pulses consist of negative charges moving from the filament to the grid, the plate of the condenser, which is on the grid side, and the grid itself, will accumulate a negative charge. Since electrons will only flow to the grid when it is positive, it is evident that the current pulses will be automatically reduced as the grid receives a negative charge, and no more current pulses will flow when the average grid voltage has become so negative that the alternating voltage, even on its maximum positive swing, does not make the grid positive relative to the filament. Actually there will be a slight leakage of the charge from the grid condenser and the grid, due to the residual gas in the old De Forest tubes which were used in this circuit. Minute pulses of current will flow which are just sufficient to compensate for this leakage.

Summarizing thus far, when the assumed oscillations of constant amplitude first strike the tube, rectified pulses flow in the grid circuit. These pulses, through the action of the small condenser j^3 cause quickly the grid to become negatively charged until the pulses practically cease. No matter how long the oscillations of constant amplitude persist, there will be no further rectification nor will there be any further change in the charge of the condenser j^3 nor of the potential of the grid.

Suppose now the received oscillations cease. By reason of the leakage, the charge on the small grid condenser will quickly dissipate and the grid will attain its original voltage again. Thus the average grid potential responds to incoming oscillations becoming negative when these oscillations are first impressed upon the tube end and returning to the normal condition when they are removed.

[fol. 523] Now assume that the amplitude of the incoming oscillations is varying, as is the case of modulated oscillations. It is obvious that the grid will become more negative the greater the amplitude of the oscillations and will return

toward the normal grid potential again as the amplitude of the oscillations decreases. The variations in average grid potential would thus follow the lower dash line curves of figures 2 to 4 of my drawing C for modulated oscillations of these types. These are audio-frequency variations; hence the average grid potential will vary at an audio-frequency rate.

Now, as I have pointed out before, the action of the tube as an amplifier entails that the plate current of the tube shall follow the variations in the potential of the grid. So, as the average grid potential varies in accordance with the audio-frequency modulation of the received oscillations, the plate current will likewise vary in the same manner. These audio-frequency current variations flow through the indicating device I, which is a telephone receiver. The sound which results will be an 800 or 1,000 cycle note or speech, depending upon the type of modulation, as was explained before.

Summarizing, the action of the three-electrode tube in the P X circuit is as follows:

Received oscillations, modulated at audio-frequency, produce rectified current pulses in the grid circuit of the tube when the amplitude of the oscillations is increasing, and thus, by reason of the grid condenser, cause the average grid potential to become more negative. When the amplitude of the oscillations is decreasing, the charge on the grid condenser leaks off and the grid becomes less negative. Thus audio-frequency variations in the average grid potential are produced which correspond to the audio-frequency modulation of the received oscillations. By reason of the amplifying or relay action of the tube corresponding audio-frequency currents are caused to flow through the telephone receivers in the plate circuit. The tube is acting as a detector and simultaneously as an audio-frequency amplifier.

The above explanation stresses the most essential features of the action of the tube in this circuit for the purpose of simplification. The complete action is somewhat more complicated. It can be seen that the grid potential is varying simultaneously at two frequencies. Thus the modulated high-frequency oscillations are varying the grid potential and at the same time the average value of the grid potential is varying at an audio-frequency rate through

the action of the charging and discharging of the grid condenser. The variations of the plate current of the tube exactly duplicate all variations in grid potential, so that in the plate circuit we find both the amplified modulated high-frequency oscillations and the amplified audio-frequency oscillations. The latter, of course, can alone affect the telephone receivers; in fact, the high-frequency oscillations can not flow through its coils. Usually a condenser called a by-pass condenser is shunted across the phones, which provides a by-pass for the high-frequency oscillations while the audio-frequency variations flow through the phones. In this simple P X circuit the amplified radio-frequency oscillations, in reality, go to waste. I have referred to this circuit previously as one which did not fully utilize the amplifying properties of the tube and to the fact that the results obtained with this circuit do not far surpass the results ob- [fol. 524] tained with a good crystal detector. It gives results which are about 50 per cent better than such a crystal and about five times as good as a two-element valve. This circuit has not been used by the Government to any extent. The circuits which have been used are the so-called "regenerative" circuits which utilize the amplified radio-frequency oscillations dsicarded in the P X circuit and give signals perhaps twenty times as strong. This result is made possible purely and simply by the amplifying property of the three-electrode tube.

In Figure 3 is shown a diagram of the circuit like plaintiff's Exhibit No. 114. A condenser h^2 is connected across the phones to provide a path of low impedance for these high-frequency currents. This condenser, however, is a high impedence for the low or audio-frequency currents and these flow through the telephone receivers. The regenerative feature is brought about by the flow of the amplified radio-frequency currents through the coil j^4, frequently called the "tickler" or "feed-back" coil, which is inductively coupled to the coil j^2. By reason of this coupling, a voltage is fed into the coil j^2 which is in phase with and is additive to the voltage fed into the same coil from the antenna. As a result, when a received radio signal sets up high-frequency oscillations in the antenna thus inducing a voltage in the coil j^2, there is simultaneously induced in the j^2 an assisting high-frequency voltage from the coil j^4. This latter voltage can be a number of times greater than the former. The currents which flow in the circuit j^2 h^1 are

multiplied according, as is also the high-frequency voltage across the condenser h^1 which is applied to the tube. Since the change in the average grid potential, as pointed out before, depends upon the amplitude of the radio-frequency oscillations, the audio-frequency variations of the grid potential and likewise the audio-frequency currents in the plate circuit of the tube will be enhanced many times, producing a greatly increased response in the telephone receivers.

The radio-frequency voltage impressed upon coil j^2 by coil j^4 can be, say, four times as great as the voltage coming from the antenna, so that the total voltage is five times as great as in the simple P N circuit. By the well known law of operation of the tube, the audio-frequency current in the telephone receivers, or what is called the signal audibility, will be five squared, or twenty-five times as great. This represents a result which is easily secured by an operator ordinarily skilled in the manipulation of such circuits. This result is only possible by reason of the amplifying property of the three-electrode device which here is utilized twice in the same tube; first, the amplification of the radio-frequency oscillations which supplies the feed-back voltage from the coil j^4, and then the amplification corresponding to the audio-frequency variations in the grid voltage which supplies the audio-frequency currents to the telephone receivers. The device is acting simultaneously as a radio-frequency amplifier, and audio-frequency amplifier, and as a converter from radio-frequency to audio-frequency or a detector. The amplifying property is of the prime importance, for in numerous instances a crystal detector is used in combination with the three-electrode vacuum tube in a similar regenerative circuit, the amplifying functions alone being performed by the tube, the detecting function by the crystal. The results are, in general, even superior to those obtained when [fol. 525] the tube acts as the detector. There is, however, no substitute for the tube as an amplifier. It will be noted that, as in plaintiff's Exhibit No. 114, I have shown a resistance *r* in parallel with the condenser j^3 in Figure 3. This resistance is universally used in detector tube circuits since the art discarded the old soft tubes. It is a high resistance, of the order of 2,000,000 ohms, and provides the leakage of current essential to restoring the grid potential to its normal value in the action of the tube as a detector as explained above. It is called the "grid leak." The grid

condenser normally has a capacity of about 0.00025 microfarad.

Even the results obtained by the regenerative circuit are dwarfed by the results which are obtained by using the pure amplifying property of the three-element device in multistage radio and audio-frequency amplifiers. For, with two tubes in tandem in a modern audio-frequency amplifier the current in the telephone receivers is multiplied four hundred to twenty-five hundred fold, with both radio and audio frequency amplification there is hardly a limit to the multiplication of the response; the signals can be millions of times greater than would be received with the simple P N circuit, so that signals which with the P N circuit would be of a strength of only one millioneth of that necessary to make them audible would become audible with such an amplifier.

The three-electrode vacuum tube and its circuits as illustrated in the P N and regenerative connections of plaintiff's Exhibits 83 and 114, for example, differ essentially in mode of operation from that of the two-electrode valve detector in the circuit of the Fleming patent. The two-electrode device in the Fleming circuit constitutes essentially a rectifying device in a single circuit in which the received oscillations are rectified and themselves flow through and are indicated by the indicator. On the other hand, the three-electrode device in the P N circuit as well as in the regenerative circuit constitutes essentially a different type of vacuum tube connected to two separate circuits neither of which performs the functions of the Fleming circuit. In the P N and regenerative circuits, while the received oscillations are increasing in amplitude, they produce rectified current pulses which charge the grid condenser, which charges leak away when the received oscillations are decreasing in amplitude or are not being received. Such rectification as occurs is not indicated in either circuit. Even if it were possible to observe this rectification it would not reproduce the audio-frequencies which the detector is intended to indicate. The rectification and flow of current is an incidental action of the tube in properly charging and discharging the grid condenser. What is indicated in the plate filament circuit employed in the three-electrode device is the audio-frequency variation in grid potential caused by the accumulated charges or discharges of the grid condenser. In short, the rectifications in the three-element

device in the circuits of my Figures 2 and 3 are not indicated in the plate-filament circuit nor in the grid-filament circuit. The received oscillations acting upon the grid and grid condenser cause the plate current to vary in a manner so that the plate circuit reproduces the radio-frequencies and also the audio-frequencies caused by the condenser accumulations and discharges.

The fundamental difference in mode of operation is clearly shown by the fact that in the Fleming circuit the feeble [fol. 526] received oscillations must themselves supply the power to actuate the indicator, while in the three-electrode circuits of Figures 2 and 3 the received oscillations are called upon only to vary the potential of an extremely small condenser, and hence supply only a negligible amount of power. The power supplied to the indicator is furnished by the "B" battery under the controlling action of the grid electrode.

In the Fleming circuit the power actuating the indicator must be less than the power of the received oscillations from which it is derived, while in the P N circuit or the regenerative circuit the power actuating the indicator can be greater than that of the received oscillations.

* * * * * * *

18. Question. Compare the operation of the two-electrode valve detector in the circuit of the Fleming patent with its operation when a battery is employed. Contrast this with the operation of the three-electrode vacuum tube.

Answer. To simplify my explanations I have assumed in general thus far that the detector, whether Fleming valve or crystal, is a perfect rectifier. Such a device would readily permit a current flow in one direction, no matter how small the impressed voltage, but would not permit any flow in the reverse direction. Unfortunately such an ideal device is not known in the art; relative to the known devices, it can only be stated that they conduct better in one direction than in the other. When an alternating voltage is applied to the ordinary rectifiers the current flow during an alternation in one direction exceeds the current flow in the reverse direction during the opposite alternation of the voltage. The difference between these currents represents the rectified or direct current. The difference in behavior of the device for alternations in the two directions is intimately linked with the characteristic curve of the device. Thus in

my answer to question 9 I pointed out that it is a matter of the bending or curvature of the characteristic curve.

If the characteristic curve is a straight line, such as is the case for an ordinary resistance coil, then the two alternations will produce equal current fluxes in the two directions and there will be no rectification. If, however, the characteristic curve is bending or has curvature as was the case for the carborundum crystal curve shown in that answer, then the rise of the curve in one direction will be more rapid than its fall in the reverse direction, or vice versa, and the current flow in the two directions will be different. The difference represents the rectified current, and it is apparent that the amount of rectified current which results depends upon how sharply the characteristic curve is bending or upon the extent of its curvature. Thus if one crystal were to show a curve with a sharper bend than another, the rectified current furnished by the first crystal would be greater and it would be a better detector. It may be that one portion of the characteristic curve of a given detector is nearly straight, while another portion is decidedly curved. If the straight portion of the curve were to come at zero voltage then when the alternating voltage is applied, so as [fol. 527] to swing equally on either side of zero, there would be little or no rectification and the device would be a very poor detector. Suppose, however, that we apply a steady voltage, frequently called a "biasing" voltage, to the detector which brings it to the portion of the curve which is decidedly curved. There will be, of course, a steady current flowing through the detector due to the biasing voltage. Now, if the alternating voltage is applied on top of, or in series with, the biasing voltage the voltage swings will be equal on either side, but since the curve is decidedly curved at the point around which the voltage is swinging, the increase in current on one swing will be decidedly more or less than the decrease in current on the other swing. Neglecting the steady current, it is clear that the alternating voltage is producing a greater current flow in one direction than in the other, viz, a considerable rectified current is produced. Thus the device becomes a good detector merely because the steady or biasing voltage has fixed the operating point at a portion of the characterictic which is more favorable to rectification. Some devices show a favorable portion of the characteristic at zero voltage and with such devices the biasing voltage is not necessary; oth-

ers show an improvement in sensitiveness when the biasing voltage is employed. For small alternating voltages the carborundum crystal is a very poor rectifier at zero voltage; it can be seen from the curve, which is Figure 2 of my drawing D, that in the immediate vicinity of zero voltage the characteristic curve of the carborundum crystal is nearly a straight line. The sensitiveness of this crystal is improved by applying a positive biasing voltage so as to bring the operation on the curved region of the characteristic. Practically all of the crystal detectors commonly used in the Navy operate so well at zero voltage that the slight improvement in sensitiveness which might be obtained with a biasing voltage is not considered of sufficient importance to justify the provision of a battery and other accessories in order to utilize it. The use of a battery in connection with the Fleming valve is identical to its use with crystal detectors. In some cases the rectification is improved when the operation is shifted to a part of the characteristic curve which has a more favorable curvature; in other cases no improvement is obtainable.

It is necessary to distinguish between an increase in sensitiveness such as is produced in some cases by the use of a biasing battery and what is meant by the technical term amplification. An increase in sensitiveness of a detector produces, it is true, an increased response in the telephone receivers, and this might be popularly termed an amplified response. Technically, however, this is not amplification, and with or without the biasing battery the crystal detectors and Fleming valve are not amplifiers. The function of the detector is to convert the received radio-frequency power over into audio-frequency power. There is always a loss in this conversion and the audio-frequency power is always less than the received radio-frequency power; in many cases the audio-frequency power is an extremely small percentage of the radio-frequency power.

The action of the biasing voltage is to improve the efficiency of the conversion; it must, however, always be far below 100 per cent in efficiency. Amplification does not involve a conversion of frequency. The frequency is kept the same, whether it be radio or audio. The power is, however, multiplied perhaps hundreds of times in a single stage [fol. 528] of amplification and this process can be repeated indefinitely. The use of a battery with a detector is optional; the use of a battery with an amplifier is indispensa-

ble by reason of the law of conservation of energy. In the case of the ordinary detector, the received energy is merely converted from one frequency to another; in the case of an amplifier the output of energy is many times the input of energy, which, of course, requires a supply of energy from a local source. The plate or "B" battery of the three-electrode vacuum tube is this local source.

When the three-electrode vacuum tube is used as a detector, it is, as I have pointed out before, both a detector and an audio-frequency amplifier. The frequency conversion will entail a loss of power which, however, may be made up by the amplifying action of the tube, so that there is a possibility in this case of obtaining an audio-frequency response which represents a greater amount of power than is contained in the received radio-frequency signal. There is no such possibility with nonamplifying devices such as the crystal or Fleming valve.

Question 19. Describe the operation of the three electrode vacuum tube as an amplifier, particularly the circuits of plaintiff's Exhibit No. 85 and No. 110, and other types of amplifiers.

Answer. The De Forest audion amplifier, which is plaintiff's Exhibit No. 85, is representative of an old type of amplifier which used the old De Forest three-electrode tubes and was the first audio-frequency amplifier employed by the Navy. Only a few of these amplifiers were put into naval service, they were soon replaced by very much more efficient instruments designed by the Navy at the Washington Navy Yard in particular by a type of audio-frequency amplifier known as the S. E. 1,000, which utilizes high vacuum three-electrode tubes. The Signal Corps of the Army did not use vacuum tubes to any extent prior to the war. During the war, however, they used extensively an audio-frequency amplifier known as the S-C-R-72 which was designed for them by the Western Electric Co. This was also an efficient amplifier which multiplied the audibility of signals some two hundred times and employed high-vacuum tubes. These amplifiers were all intended and designed to handle audio-frequency currents and would only operate to amplify such currents. These currents might be the audio-frequency currents resulting from the action of a detector of any type on received radio-frequency signals, or the same amplifiers could be used to amplify audio-frequency currents in any other field. Thus the S C R-72

amplifier was extensively used in connection with the reception of ground signaling currents, in which method of signaling only audio-frequency currents were employed. It was also used to tap the telephone lines of the enemy. Any of these amplifiers used with a telephone receiver constitutes in effect a telephone receiver which is hundreds of times more sensitive. They replace such a telephone receiver in the various circuits and are designed to have approximately the same electrical characteristics, such as electrical impedance, as is possessed by the telephone receivers.

The more modern amplifiers do not differ greatly, excepting in efficiency, from the circuit of plaintiff's Exhibit No. 85. In the modern amplifiers, the three batteries marked B^2 are replaced by a single battery which supplies [fol. 529] the plate voltage to all of the tubes. Also the amplifier of plaintiff's Exhibit No. 85, is peculiar in that one terminal of the secondary winding of the transformers 1, 2, and 3 is left open and not connected to anything. In all but these earlier amplifiers this terminal of the secondary winding is connected to the negative terminal of the filament, for it is desired to apply the voltage of this secondary winding between the grid and filament electrodes of the tube. In fact, the audio-frequency amplifier shown in defendant's Exhibit D, which is also one of the early De Forest amplifiers, shows this connection completed in the usual manner.

The condenser *h*, which is in the primary winding of the transformer 2 (of Exhibit No. 85), is also not usual in later types. The presence of this condenser shows that this amplifier when used in radio signaling is intended to be used with a crystal detector. Mr. Waterman is incorrect in his statement in answer to question 33, in which he says:

"Referring again to Mr. Graham's diagram, Exhibit No. 85, the two left-hand terminals X Y correspond to X Y on the diagram just produced, being the two terminals which would be connected to the receiver in place of the telephone of Exhibit No. 83."

For in the circuit of Exhibit No. 83, which is the P N detector circuit reproduced as Figure 2 of my drawing F, the plate battery "B" is applied to the plate of the tube through the indicator I which is a telephone receiver and the plate current of the tube flows through the telephone receiver. If now the terminals X Y of Exhibit No. 85 were

connected in place of the telephone receiver, as Mr. Waterman says, the condenser *h* would be put in series in the plate circuit of the tube. Such a condenser is, of course, an open circuit for direct currents and the plate current of the tube could not flow, thus rendering the tube inoperative.

This particular amplifier is therefore not intended for use with a three-electrode vacuum tube detector but for use with a crystal detector, which, as Mr. Clark testified, was the customary method of use of these early amplifiers in the Navy.

In my drawing G which I now offer is shown in Figure 1, a circuit diagram of the Navy type S. E. 1,000 amplifier. This amplifier is intended for use with either a crystal or three-electrode vacuum tube detector, the terminals X Y being connected in place of the telephones in such circuits. It will be noted that there is no condenser such as *h* of plaintiff's Exhibit No. 85 in the primary winding of the transformer T_r1; likewise the secondary circuits of the transformers T_r1 and T_r2 are connected to the grid and filaments of the first and second tubes, respectively.

The later types of amplifiers do not have the condenser *h* and can be used with crystal or vacuum tube detectors.

The operation of such an amplifier is very simple. Where substituted for the telephone receivers, the audio-frequency current which was flowing through the winding of the receivers will flow instead through the primary winding of the first transformer T_r1. This winding is designed to have the same impedance as the usual telephone receiver and hence the same audio-frequency current will flow through it and the same voltage be applied to its terminals.

The secondary winding has three to ten times as many turns as the primary winding in the usual designs, hence the transformer is what is known as a step-up transformer [fol. 530] and the voltage across the secondary terminals is several times higher than that applied to the primary. This result is possible only because of the fact that the grid circuit of the three-electrode vacuum tube, to which the secondary terminals are connected, takes an inappreciable amount of power and hence the current supplied by the secondary circuit of the transformer is negligibly small. A transformer is not an amplifier; the power in the secondary is, if anything, less than the power supplied to the primary. Hence, if the secondary voltage is to be higher

than the primary voltage, the secondary current must be correspondingly less than the primary current. The secondary voltage of T_r1 is applied between the grid and filament of the first tube and by reason of the controlling action of the grid a corresponding audio-frequency variation is produced in the plate current of the tube which flows through the primary of the second transformer T_r2. Here we have amplification contributed by the vacuum tube, for the power in the primary winding of this second transformer will be many times greater than the power in either primary or secondary winding of the first transformer. Even in the older amplifiers, such as shown in plaintiff's Exhibit No. 85, the audio-frequency current in the primary of the second transformer would be five times as great as that in the primary of the first transformer, which means a twenty-five fold amplification of power.

In the later types, such as the S. E. 1000 and S. C. R. 72, the power will be two hundred to four hundred times greater. The voltage across the secondary winding of T_r2 is applied between the grid and filament of the second tube. Again, amplified currents are produced in the plate circuit of this tube which flow through the telephones. The audio-frequency power in the telephones in the case of this S. E. 1000 amplifier is about one hundred and sixty thousand times as great as the power in the primary of the first transformer. This corresponds to a multiplication of current of four hundred times, or the amplifier and phones constitute an indicator which is four hundred times more sensitive than the phones alone. In many amplifiers arrangement is made so that the telephone receivers can be substituted in place of the primary winding of the second transformer if only moderate amplification is desired. In this case the amplifier would consist of one transformer and one three-electrode vacuum tube with the telephone and would be called a single-stage amplifier. If greater amplification is desired, the second transformer and tube is employed and the phones are moved to the plate circuit of the second tube as shown. This is called a two-stage audio-frequency amplifier. The S. E. 1000 and S. C. R. 72 are amplifiers of this type, and provision is made in the S. E. 1000 amplifier to use one or two stages as desired.

In modern efficient amplifiers more than two stages of audio-frequency amplification are rarely employed. The older type of plaintiff's Exhibit No. 85 uses three trans-

formers and three tubes and is a three-stage amplifier. Each stage, however, only multiplies the current about five times, so that the three stages multiply by 5 by 5 by 5 or 125 times, which is less than that obtained with the two stages of the later instruments.

Plaintiff's Exhibit No. 110 might easily be confused with the three-stage audio-frequency amplifier of plaintiff's Exhibit No. 85, and is, in fact, so confused in Mr. Water- [fol. 531] man's description. In reality Exhibit No. 110 shows a combination of the P-N detector circuit and a two-stage audio-frequency amplifier. In my Figure 2 of drawing G, which reproduces Exhibit No. 110, the dash line *a b* and terminals X Y are shown in order to prevent such confusion. The circuit to the left of the dash line is the typical P-N detector circuit and is entirely similar to my Figure 2 of drawing F and plaintiff's Exhibit No. 83 which show this P-N circuit. The presence of the usual grid condenser in the grid lead is to be noted. The circuit to the right of the dash line or from the terminals X Y is a typical two-stage audio-frequency amplifier circuit.

In other words, plaintiff's Exhibit No. 110 shows a P-N circuit in which the telephone receiver is replaced by a two-stage audio-frequency amplifier. The conversion from radio to audio-frequency takes place in the detector circuit to the left; to the right only audio-frequency currents are employed. In his answer to question 34, Mr. Waterman describes the three tubes of this circuit as being detector bulbs; thus he states:

"Three detector bulbs T, T^2, T^3 together constitute the detector, R being the telephone indicator."

This statement is nonsensical; the tandem connection of three detectors is unknown in the art. There is only one conversion of frequency to be performed, viz; from radio to audio. This is accomplished in the first tube circuit. What possible function could any further detectors perform? As a matter of fact, as stated above, tubes T^2 and T^3 act only as amplifiers; they serve only to amplify the audio-frequency output of the first tube.

A similar idea is apparently contained in a later statement in this same answer of Mr. Waterman and with reference to this same circuit.

Thus he says:

"The operation of a tandem series of bulbs is the same substantially as that of a single bulb; that is to say, each

successive bulb repeats the action of the one before it. Thus the first bulb T′ (referring to fig. 88a) detects * * *."

The reproduction of figure 88*a* of the Navy manual for 1915 is plaintiff's Exhibit No. 110 and my figure 2 of drawing G. From this quotation of Mr. Waterman the natural inference to be drawn is that he is stating the operation of the three tubes in this circuit to be identical; viz, all three tubes are detectors. Such a statement is not in accordance with the facts, as would be recognized by the veriest amateur in the radio art. It is true that all three tubes are amplifying, for the three-electrode vacuum tube is always an amplifier. As I have pointed out before, the first tube is detecting and amplifying also. It is, however, called a detector in the art by reason of its detecting action. The second and third tubes are amplifying alone and are known in the art as amplifiers. They are not detectors and are not called detectors by anyone skilled in the art.

In the circuit of Exhibit No. 85, all three tubes are acting the same, viz, all three tubes are purely and simply audio-frequency amplifiers. There is sense in a tandem arrangement of amplifier tubes, viz, each tube multiplies the radio-frequency currents supplied by the preceding tube.

In recent years there has been a very great development in the field of radio-frequency amplification; that is, in am-[fol. 532] plifying by means of three-electrode vacuum tubes the received radio-frequency oscillations before subjecting them to conversion to audi-frequencies in a detector. In radio-frequency amplification there are three well recognized types of amplifiers called resistance, reactance, and transformer type amplifiers. These are named from the type of coupling element utilized between the vacuum tubes, which element serves to apply the amplified output of one tube to the input of the succeeding tube. The transformer type of radio-frequency amplifier is the type which has been most widely used, especially by the Government. The circuit is entirely similar to that used in the audio-frequency amplifiers described above, though the transformers themselves are markedly different. The radio-frequency transformers have relatively few turns, usually the same number in the secondary as in the primary, and are either air core or employ iron cores made up of iron sheets having a thickness of a few thousandths of an inch. Usually radio-frequency

amplification is employed together with audio-frequency amplification, and the complete instrument, called a radio-audio amplifier, comprises several stages of radio-frequency amplifications, a detector to convert to audio-frequency, and several stages of audio-frequency amplification. The detector is, for convenience, usually a three-electrode vacuum tube detector though in numerous instances a crystal detector is employed. As employed by the Navy, a radio-audio amplifier utilizes six vacuum tubes, three of which serve to amplify the radio frequency currents, one is a detector, and two amplify audio-frequency currents. A simplified circuit diagram of such an amplifier is given in my drawing H. On the left is the usual antenna and receiving circuit drawn in dash lines, which is, of course, not included in the instrument.

The radio-frequency voltage across the condenser C, resulting from the received signal, is applied between the grid and filament electrodes of tube 1. By reason of the controlling action of the grid, a radio-frequency current variation of like wave form is produced in the plate current and flows through the primary of the transformer T_1. The voltage at the secondary terminals of this transformer can be, say, five times greater than the original voltage impressed on the grid of tube 1. This is applied to the grid of tube 2 and in a similar manner produces a voltage on the input of tube 3 which is again multiplied five times. The radio-frequency voltage applied to tube 4 will then be 5 by 5 by 5 or one hundred and twenty-five times the original voltage applied to tube 1. Tube 4 is the detector tube and includes in its grid lead the usual grid condenser c' and grid leak r. By the use of radio-frequency amplification we have therefore increased the radio-frequency voltage applied to the detector by one hundred and twenty-five times. By the well-known law of operation of such a detector, the audio-frequency current output will be 125 squared, or 15,600 times as great as it would be were such amplification not utilized. The power is proportional to the current squared and hence is two hundred and fifty million times as great as without amplification. The audio-frequency output current of the detector tube is then amplified say four hundred times through the audio-frequency transformers T_4 and T_5 and tubes 5 and 6 in the manner described above.

[fol. 533] The resulting audio-frequency current in the telephone receivers is therefore 400 by 15,600 or over six million times as great for the same received signal as would be received with a detector tube alone. Of course, any signal that would produce an audible response with a detector alone would be far too powerful for such an amplifier to handle. The amplifier would be used to receive signals thousands of times too weak to be received on a detector alone. The values which I have given above represent moderate values, for the amplification obtained in such radio-audio amplifiers employing three-electrode vacuum tubes. I have myself designed and built a number of such amplifiers for the Navy and have made hundreds of measurements of both the radio and audio amplification obtained with such instruments.

The two-electrode valve is incapable of use as an amplifier and there is no possibility of utilizing it in such tandem arrangements as described above for either audio or radio frequency amplification. When by reason of residual gas the two-electrode tube is given a falling characteristic, as in the demonstration before Judge Mayer, there is a possibility that it might amplify after a fashion in a laboratory demonstration. There is the same possibility in the mercury arc which was tried out and discarded in wire telephony. However, this gas action in the two-element valve would be of absolutely no utility commercially, because it is thoroughly unreliable in operation, would require constant attention and adjustment, and the device would have a life of only a few hours. As to the use of such devices in tandem, I cannot conceive how this could be done. It is a two terminal device with a single circuit, and as such I cannot imagine how it would be connected into such circuits as are employed with the three-electrode vacuum tube, which is a three-terminal device with two separate circuits. It has surely never been done practically. Suppose, however, it were possible and one connected up six of these tubes in tandem in an amplifier. Each tube would have to be separately adjusted to the critical condition wherein it exhibited the following characteristic: Each tube would be continually changing, so that doubtless by the time the second or third tube were adjusted the first would be out of adjustment again. It would seem to be beyond human skill to get such an arrangement operating and to keep it in operation.

On the other hand, the amplifiers employing the three-electrode vacuum tube are dependable in operation and are being used by perhaps a hundred thousand novices in the radio art, viz, the broadcast listeners, in addition to their use by hundreds or thousands of commercial operators. These amplifiers use high vacuum three-electrode tubes and are not at all critical in operation. Any reasonable value of filament current or plate voltage can be employed, and the life of the tubes when not abused may be a thousand or ten thousand hours of service, viz, it is of the same order as the life of the ordinary incandescent lamp.

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[fol. 534] 20. Question. Describe the operation of the three-electrode vacuum tube as an oscillation generator, in particular referring to the ultra-audion circuit of plaintiff's Exhibit No. 109, the vacuum-tube receiver circuit of plaintiff's Exhibit No. 114, and the vacuum-tube transmitter circuits of plaintiff's Exhibit No. 116.

Answer. In my answer to question 8, I have pointed out that there are four important uses of the three-electrode vacuum tube.

(*a*) An amplifier, at either radio or audio frequency.

(*b*) A combined amplifier and radio-frequency detector.

(*c*) An oscillation generator.

(*d*) A combined oscillation generator and radio-frequency detector.

The use (*a*) has just been considered in detail in my answer to question 19. The use (*b*) was discussed in my answer to question 17, in which the operation of circuits such as the P-N detector and regenerative circuit was explained. The uses (*c*) and (*d*) will now be treated. The vacuum-tube circuits of plaintiff's Exhibit No. 116 are intended to show the typical circuits used with the vacuum tube as an oscillation generator. As such they would illustrate the use (*c*). Unfortunately, three of the four circuits which Mr. Clark has given in this exhibit are inoperative for reasons which I shall point out. The only operative circuit in this exhibit is the one marked "General Electric (No. 1)." I find circuits resembling the one marked "De Forest" and the one marked "Western Elec-

tric" in the publication Naval Aircraft Radio, which is plaintiff's Exhibit No. 117, but it appears that, in simplifying these circuits, Mr. Clark has left out features which are essential to the operation. Also I find a circuit resembling the one marked "General Electric (No. 2)" in plaintiff's Exhibit No. 118. This circuit is, however, also inoperative as depicted by Mr. Clark.

The three inoperative circuits utilize what is known in the art as a "parallel plate battery" connection. This type of circuit to be operative requires a radio-frequency choke coil in series with the plate battery marked B^2 in the diagrams of plaintiff's Exhibit No. 116. Such coils are shown in the original circuit diagrams. The operative circuit marked "General Electric (No. 1)" utilizes a "series plate battery" and does not require such a choke. In the circuit marked "General Electric (No. 2)" Mr. Clark has also omitted the grid leak resistance across the grid condenser c_1 which likewise would prevent operation when high-vacuum tubes, such as are used with this circuit, are employed. In fact, a common method of stopping the oscillations in signaling with such a transmitter is to open up the grid leak resistance with the signaling key or to insert a condenser without a grid leak in the lead to the grid.

These circuits, when properly drawn, would be representative of the use of a three-electrode vacuum tube solely as an oscillation generator, in which case the tube is used for the transmission of radio signals, both telegraph and telephone, as distinguished from the use of the tube for the reception of such signals. The tube is functioning as a high-frequency alternator. The tubes used for this pur- [fol. 535] pose are evacuated to an extremely high degree, for in many cases a thousand volts or more is employed for the plate voltage or what is called the "B" battery. Normally the tubes are also very much larger than the tubes used in reception.

The use (*d*) of the three-electrode vacuum tube as a combined oscillation generator and detector is illustrated in the ultra-audion circuit of plaintiff's Exhibit No. 109 and the vacuum tube receiver circuit of plaintiff's Exhibit No. 114. These are the circuits utilized in the so-called "beat-note" method of reception, which is the method employed for the reception of unmodulated oscillations or continuous waves.

The art has progressed strongly toward the exclusive use of continuous waves in radio-telegraphy. To-day, almost without exception, continuous waves are employed in high-power long-distance communication. To receive these waves the beat method is universally employed, which method, as I have pointed out before, requires a local oscillation generator at the receiving station.

When these local oscillations are properly combined with the incoming received oscillations, modulated oscillations are obtained. The local oscillator is made to generate oscillations which differ slightly in frequency from the received oscillations, hence at one instant the local oscillations will be in step with the received oscillations and a little later will be out of step. When the two oscillations are in step, they will assist each other and the combined oscillation will be increased in amplitude; when they are out of step, the two oscillations will oppose and the combined oscillation will be decreased in amplitude. This is similar to the "beats" which occur in music when two notes slightly different in pitch are sounded simultaneously, in which case the ear can recognize the swelling and subsidence of the amplitude of the oscillations. The number of times per second that the oscillations get into step, or the number of "beats" per second is easily shown to be equal to the difference of the two frequencies in the case of both the sound and radio oscillations. Thus, in the latter case, if the received oscillations have a frequency of 100,000 and the local oscillations are adjusted to a frequency which is 1,000 per second higher or lower, the beats will occur at a rate of 1,000 per second, viz. the combined oscillation will rise and fall in amplitude 1,000 times per second. Thus the combined oscillation is modulated at a frequency of 1,000 per second.

It must be remembered, however, that the oscillations are still high-frequency oscillations even though their amplitude is varying at an audio-frequency rate. The oscillations are similar to that shown in Figure 2 of my drawing C. As pointed out before, these oscillations will not actuate a telephone receiver so as to produce an audible response. In order to bring this about, the oscillations must be rectified or distorted by a detector. Then a current varying at a frequency of a thousand per second is obtained and this will produce a response in the phones. To employ this important method of reception it is obvious

that two devices are required at the receiving station, viz., an oscillation generator and a detector. The oscillator can, theoretically, be any type of radio-frequency oscillation generator; the detector can be any type of detector. Thus a Poulsen arc could be employed as the local oscillation generator and a crystal as the detector. Practically, however, the Poulsen arc is cumbersome for a portion of a [fol. 536] receiving equipment and also produces a hissing noise in the telephone receivers, so that it is not a satisfactory device for such reception. The three-electrode vacuum tube is the only practical oscillation generator for this purpose. Any good detector, such as the crystal, can be utilized or another three-electrode vacuum tube can be employed as the detector. Actual measurements show that in both cases the results are practically identical.

It is apparent therefore that this important method of reception is made practically possible solely by reason of the oscillating property of the three-electrode vacuum tube. It is also possible with the three-electrode vacuum tube to combine in one tube the functions of oscillation generator and detector, which is, of course, a convenience. This is exemplified by the circuits of plaintiff's Exhibits Nos. 109 and 114. Both of these circuits employ means to make the vacuum tube operate as an oscillation generator to supply the local oscillations and also employ the typical grid condensers marked j^3 and h^3 which are utilized in the detecting operation. The latter circuit is a more recent one; it employs high-vacuum tubes and has, therefore, also the grid leak resistance L. This method of reception in which the same three-electrode vacuum tube operates as an oscillation generator and detector is called the autodyne or self-heterodyne method of recepion. The method of reception is also frequently employed in which a three-electrode tube acts as an oscillation generator alone and another three-electrode tube or crystal acts as the detector. This method is called the heterodyne method of reception.

The operation of the vacuum tube as an oscillation generator, whether used as a radio transmitter or to produce local oscillations in beat note reception, is dependent upon the fact that it is an amplifying relay. If an alternating voltage is applied to the grid circuit or input circuit of the tube, the controlling action of the grid electrode pro-

duces an alternating current of like frequency and wave form in the plate or output circuit. The alternating current power required to operate the grid is small compared to the alternating current power produced in the output. Suppose that instead of applying the alternating voltage to the grid from an external source, we take some of the output power of the tube itself and use that to excite the grid. Then the device becomes a self-generator of oscillations. In all circuits, therefore, for generating oscillations with the three-electrode vacuum tube there is a so-called "feed-back" feature by which the voltage and power to actuate the grid circuit of the tube is fed into this circuit from the plate or output circuit. This feed-back can be accomplished in a great many ways and hence there are numerous circuits for generating oscillations with the three-element device. This feeding back of power from the output to the input of the tube is similar to the action of the regenerative circuit already described in my answer to question 17. In fact, it is only necessary to increase the amount of voltage fed back in this circuit to transform it into an oscillation generator. Thus the same circuit, if provided with a variable feed-back arrangement, can be used as a regenerative circuit or an oscillation generator.

The regenerative condition is employed as explained previously, where modulated oscillations are being received and leads to an enhanced response by reason of the more complete utilization of the amplifying property of the tube. The oscillating condition is used either when unmodulated [fol. 537] oscillations or continuous waves are being received by the beat method, in which case the tube is acting as both *as* an oscillation generator and detector, or for the generation of radio oscillations to excite the antenna in the transmission of radio signals, in which case the tube is an oscillation generator alone. In the latter case the grid condenser and grid resistance are not requisite but are frequently employed for a purpose entirely different from the detention use as will be explained later.

Also when the tube is used as a radio transmitter the indicator R of plaintiff's Exhibit No. 114 corresponding to the telephones of Figure 3 of my drawing F are not required and are not present in the circuit. Such a typical circuit for utilizing the three-electrode vacuum tube as an oscillation generator is shown in Figure 1 of my drawing

I, which I now offer. This circuit is similar to those just mentioned. The batteries "A" and "B" serve, respectively, to heat the filament and supply the voltage to the plate. The feed-back from the plate circuit to the grid circuit is effected through the magnetic coupling or induction between the coil j^4 and the coil j^2.

If this coupling is at first very loose, so that only a feeble voltage is induced in coil j^2, no oscillations will be set up. As the coupling is increased the regenerative action increases; that is, a given alternating voltage impressed upon the circuit j^2 h^1 will produce greater and greater currents in that circuit because of the assisting voltage furnished by the coil j^4. Finally as the coupling is increased to a certain point the tube will itself start to generate oscillations without the need of any impressed alternating voltage from the outside. The question might be asked "What starts the oscillations?" A similar question might be asked with respect to a ball balanced on a needle point, viz, "What starts it falling?" Some little accidental disturbance destroys the balance; the forces thus brought into play destroy the balance still further and the fall is accelerated. In the case of the oscillating tube, we must assume some slight initial disturbance which produces a minute electrical oscillation in the circuit j^2 h^1, and hence applies a minute voltage to the grid of the tube. By reason of the controlling action of the grid a corresponding oscillation in the plate current is produced which flows through the coil j^4. Because of the coupling between coils j^4 and j^2, an alternating voltage is induced in the circuit j^2 h^1 which will assist the initial oscillation and increase it.

Thus the voltage applied to the grid of the tube will be increased and the corresponding variations of plate current will become greater. This in turn leads to an increased e. m. f. induced back to the input circuit through the coupling between coils j^4 and j^2. This cyclic action continues indefinitely. The strength of coupling between these coils which is required to produce oscillations is such that on each cycle the assisting voltage is increased more than the cycle before. If the coupling is such that the increase in the assisting voltage becomes less on each succeeding cycle, then only regeneration is obtained. For example, if the increase in the assisting voltage is only half as great in each succeeding cycle the final e. m. f. will be the sum of a series such as—

$$1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \text{---},$$

which is equal to 2. In this case a given alternating voltage will produce twice the currents and voltages in all parts [fol. 538] of the circuit which it would produce were the coupling between j^1 and j^2 absent. The effect will cease when the voltage ceases. If, however, the coupling is sufficiently strong so that the assisting e. m. f. is doubled on each cycle, the final e. m. f. will be the sum of a series

$$1 + 2 + 4 + 8 + 16 + \text{---},$$

which is infinite. This indicates that an initial disturbance will grow without limit. The oscillations start to grow in this manner, but, as they increase to a large amplitude, limitations finally arise which prevent a further growth and the oscillations will then persist indefinitely at the maximum value to which they have grown. The limiting value of the amplitude is imposed by limitations in the power that can be drawn from the plate battery with a given circuit and vacuum tube and by the inevitable power losses which increase rapidly as the oscillation increases beyond a certain point. One of these power losses which limits the useful output of the tube takes place in the grid circuit. When the oscillations are small, the alternating voltage on the grid is also small; no appreciable current flows between the filament and grid of the tube and there is no appreciable power loss in this portion of the circuit. As the oscillations grow, however, and the amplitude of the oscillating voltage on the grid becomes larger and larger, on the positive alternation the grid becomes considerably more positive than the filament and on each swing pulses of current flow from the filament to the grid. These pulses are not indicated nor are they useful in the operation of the tube, and in fact exert a detrimental effect in the operation of the tube as an oscillator, for they take power away from and reduce the ampiltude of the oscillations. They represent, therefore, a loss of power in the apparatus. To reduce this loss, it is possible to make the initial voltage of the grid of the tube negative with respect to the filament by including what is known as a "C" battery in the connection between the filament and grid electrodes as shown in Figure 2 of my drawing I. This battery is poled with the negative terminal toward

the grid. In this manner, since we start with the grid at at considerable negative potential, it is made possible for the oscillations to grow to a higher value before the grid begins to swing positive with respect to the filament and the power losses from this cause are reduced. This requires, however, an additional battery. Another method of accomplishing the same result, shown in Figure 3 of drawing I, is to include a grid condenser h², and grid leak resistance *r* in the lead to the grid, which has the effect of making the evil mitigate itself. For when the grid begins to take current this current must flow away from the grid through the grid leak resistance. This current is a flow of negative electrons from filament to grid inside the tube and from grid to filament in the external circuit. The voltage drop across the resistance *r* makes the grid negative with respect to the filament when the objectionable grid current begins to flow; the more negative becomes the grid automatically, thus mitigating the loss of power from this source. It is evident that the purpose of the grid condenser and grid leak in the vacuum tube transmitter circuit is entirely different from that in detecting tube circuits. We are here not concerned with detection at all, for there are no received signals to detect nor is there any indicator to actuate.

[fol. 539] In the circuits of my drawing I the transmitting antenna is not shown. Such an antenna is a capacity and can be connected in place of the condenser h¹. This is called a "direct-connected" tube transmitter circuit. Or the antenna can be in a separate circuit tuned with an inductance and coupled to either of the circuits of my drawing I. This is called a "coupled" tube transmitter.

The complete diagrams of the circuits used with the oscillating vacuum tube frequently appear quite complicated but usually can be simplified to one of the elementary types shown in my drawing J. For simplicity, I have eliminated the customary batteries from these typical circuit diagrams, and while I will name these circuits as I am accustomed to speak of them and hear them mentioned, I am not positive of the identity of the originator of these circuits. Figure 1 of my drawing J shows the so-called Meissner circuit, perhaps the earliest circuit used. In this diagram the oscillations in the tuned circuit L_3 C are sustained by the induced voltage fed by the coil L_2, in the plate circuit, to the coil L_3. The voltage to work the grid

is fed to the coil L_1 from the coil L_3. In the Hartley circuit of Figure 2, direct coupling is utilized instead of the inductive coupling of the Meissner circuit, thus eliminating the coil L_3. In the tuned plate circuit of Figure 3, the condenser C is connected across the soil L_2 alone; the voltage to actuate the grid is derived from the coupling between coil L_2 and coil L_1. The tuned grid circuit of Figure 4 has the condenser across coil L_1; the voltage to maintain the oscillations is derived from the plate circuit by the coupling between L_2 and L_1. The Colpitt's circuit of Figure 5 is likewise a direct-coupled circuit like Figure 2, excepting the condensers C_1 and C_2 replace the coils L_1 and L_2 of Figure 2. The voltage to maintain the oscillations is applied at the terminals of C_2 while the voltage across C_1 actuates the grid. Either a series or parallel plate battery connection can be used to apply the plate battery voltage to the tube in the circuits of Figures 1-4. When the parallel connection is utilized, a choke coil must be connected in series with the battery and a condenser inserted to prevent a short-circuit of the battery. In Figure 5, because the filament is insulated by the condensers C_1 and C_2, the parallel connection must be used. Also in this circuit a condenser must be used to prevent the high voltage of the plate from being applied to the grid also through the coil L. A grid leak resistance or choke coil must also be used to provide leakage between the grid and the filament. In my drawing K, I show the series and parallel plate battery connections as applied to the circuit of Figure 4 of drawing J. In the series connection Figure 1, the plate battery is applied through the coil L_2. In the parallel connection, Figure 2, the plate battery is applied through a choke coil L_3, and the condenser C″ prevents a short-circuit through the coil L_2. This circuit is identical in essentials with the General Electric (No. 2) circuit of plaintiff's Exhibit No. 116, excepting that the necessary choke coil was omitted by Mr. Clark. In a transmitter directly connected to the antenna, the antenna replaces the condenser C of my diagrams excepting in Figure 5, where the antenna replaces the condenser C_2.

[fol. 540] 21. Question. Point out the difference in structure and mode of operation of the Fleming valve in the circuit and as shown in the Fleming patent with the Audion or the three-electrode vacuum tube in the P N circuit, re-

ferring, in particular, to the comparison as made by Mr. Waterman in his answer to question 34.

Answer. The Fleming valve as shown in the Fleming patent is identical in structure with the device shown in the Edison patent No. 307031 of October 21, 1884, and illustrated in my Figure 1 of drawing A. Both structures consist of an incandescent filament and cold plate insulated from each other within an evacuated inclosure and both devices utilize the emission of electrons from such an incandescent filament and the flow of these el-etrons through the space between the filament and the plate. The shape and location of the cold plate is somewhat different in the two cases. Edison shows a plane plate located between the two legs of the filament while Fleming shows a cylindrical plate surrounding the filament. This, however, is an immaterial difference which does not change the principle of operation.

The three-electrode vacuum tube has a third electrode called the grid which is utilized as a sensitive control member over the electron flow between the hot filament and the cold plate. The addition of this third electrode and the manner of its use gives the device new properties and a new mode of operation, not possessed by the two-element device. And it is the addition of this grid electrode and the new mode of functioning, which the grid made possible, that is entirely responsible for the use of thermionic vacuum tubes in radio signalling Mr. Waterman, in his answer to question 34, describes the grid as "a bit of wire bent back and forth to form a sort of grid." In the introduction to his book on The Thermionic Vacuum Tube, Dr. Van Der Bijl thus describes the results of introducing this "bit of wire" into the two element valve:

"In fact, the insertion of the grid into the valve resulted in a device of tremendous potentialities—one that can justly be placed in the category with such fundamental devices as the steam engine, the dynamo, and the telephone."

And on page 42 Van Der Bijl states:

"It is hardly necessary to say that the insertion of the grid has made the audion a device of immense practical importance and enabled it to perform functions that would otherwise have been impossible."

Also Dr. W. H. Eccles, of England, a recognized authority on radio matters states, in his article "The three-electrode thermionic vacuum tube and the revolution in wireless telegraphy," in the Radio Review, published in England, October 1919 (p. 26):

"During the war dark hints reached the civilian that a revolution was taking place in wireless telegraphy, the principal agent in which was reported to be an instrument called a 'valve,' a 'lamp,' or a 'tube.' This instrument seemed to have risen suddenly into a predominant position among all the apparatus of the wireless experimenter and operator and appeared to be of use in every corner of [fol. 541] his outfit. The complete name of the instrument is the three-electrode thermionic vacuum tube. It must be emphasized that it is the three-electrode valve, and not the valve with two electrodes, that has been responsible for the overthrowing of the old methods and apparatus. That it has been a veritable revolution can be seen by comparing the common practice in wireless telegraphy of 1914 with that of 1919."

Mr. Waterman argues that in the Fleming valve there is a single cold element while in the three-electrode device "the cold element is divided into two."

A mere glance at the construction of the grid elements of modern three-electrode vacuum tubes is sufficient to dispel the contention that the fearful and wonderful structures which constitute the grid elements of these tubes are a mere subdivision of the single cold plate of the Edison and Fleming tubes or else the designers of these tubes have let their imaginations run riot. As a matter of fact, the designer of these tubes can predict in advance from mathematical formulas derived from fundamental electrical laws, exactly how the controlling effect of these grid structures depends upon the size of the individual wires which makes up the grid mesh; how it depends upon the distance between these wires and the location of the grid element relative to the filament and plate electrodes. The substitution of a metal plate for the grid structure would be ruinous to the operation of the device. If in the use of the three-element device, the grid and plate were connected together electrically where the leads to these elements emerge from the vacuous space, so that in all circuits and uses these two elements would be at the same

electrical potential at each instant and would merely share the current flowing to them, then it would be correct to state that the Fleming cold element has merely been divided into two. The device would, however, under this condition of use, be a two-element tube, would function in a manner identical with the Fleming valve, and could accomplish no more than could be accomplished with the Fleming valve. This is well understood in the art and is utilized when it is desired to convert a three-electrode tube into a two-electrode tube when only the rectifying property of the latter device is required.

In the use of the three-electrode vacuum tube as a three-electrode device the grid and plate are operated at different voltages, the plate may have a positive voltage of 20, 40, or several hundred volts, while the grid may be at approximately zero voltage or may have a negative voltage of 20 volts; these two elements are connected to different circuits or parts of a circuit; the grid will be varying so as to become more positive at the same instant that the plate is becoming less positive, a considerable current will be flowing to the plate while no current is flowing to the grid. It is evident that the grid and plate are two separate, independent elements and not a single element divided into two.

As a matter of fact, the Fleming valve is a two-element device and a two-terminal device, having only two terminals to which connections are made to the external circuit while the three-electrode vacuum tube is a three-element device and a three-terminal device having three terminals to which connections are made to three different points of the external circuit or circuits. The two filament terminals are considered, of course, as a single terminal being connected together by the filament itself.

[fol. 542] It is the third electrode and hence the third terminal which gives the three-electrode tube the new and wonderful property of amplification not possessed by the two-terminal device. To exercise this property, the third or grid electrode must be connected to a different external circuit or different part of the external circuit. It is obvious that a device having only two terminals can not be employed in the circuits of a device having three separate and distinct terminals connected to three separate and distinct points of the circuit. If this is attempted two of the points of the circuit which were formerly separate and dis-

tinct must be brought together and made to coincide and the circuit is changed and the functioning is changed. I am surprised to find in his answer to question 34 that Mr. Waterman says this obviously impossible thing can be done; thus he says, "The Fleming valve may be used in the P N circuit." This statement is absolutely contrary to fact. In this P N circuit the points of the circuit which are connected to the grid and plate electrodes are and must be at widely different steady voltages, the point connected to the grid has approximately the potential of the filament while the point connected to the plate is twenty volts or more positive with respect to the filament depending upon the voltage of the battery B^2, the variations in potential of these points when signals are being received are also different: at the instant the point of connection to the grid is becoming more positive, the point of connection to the plate is becoming less positive and vice versa. Further, in this P N circuit the three-element device is functioning both as a detector and amplifier, as I have explained before. Suppose we try to put the Fleming valve in this circuit. We have now a two-terminal device instead of a three-terminal device; either we must utilize only two of the points of connection with the circuit leaving the other disconnected, or we must connect two of the points of the circuit together and use them as one point. The first alternative renders the Fleming valve inoperative for we leave either the receiving circuit or the indicator out in the cold. The second alternative destroys the P N circuit and we get a different circuit and a different mode of functioning. For when the connection is made everything changes, the two points of the circuit which were at different potentials are immediately brought to the same potential, likewise these two points must now vary in potential together.

What has been done is to short-circuit these two points and a short circuit in electrical circuits between points at different potentials is a matter of decided importance. In this destroyed P N current the Fleming valve is, at best, no better off than in the circuit of the Fleming patent, even if the circuit does superficially resemble the P N circuit. The device is a detector only and is even no better as a detector.

Conversely, how are we going to use the three-terminal device in the circuits of the two-terminal device? We must either leave one of the terminals disconnected or connect two of them together and use them as one terminal. In

either case we would get the functioning of the two-terminal device and no more; in fact the latter alternative is a well-recognized way of converting a three-electrode tube into a two electrode tube as I have mentioned before.

Mr. Waterman discusses the single circuit of the Fleming patent and then the P N circuit used with the three-electrode [fol. 543] audion and then makes the statement that "These two forms of circuit I may say are very well known equivalent forms." It is true that two well known equivalent forms of circuit can be used with the Fleming valve just as two well known equivalent forms of circuit can be used with the three-element valve. But neither of these equivalent forms of circuit which can be used with the two-element valve nor any other circuit which can be used with the two-element valve is the P N circuit. The two equivalent forms of circuit are analogous to the series and parallel connections of the plate battery which I have already considered in connection with the three-electrode device. This artifice can be applied to split up and separate out, currents of different frequencies so as to make them flow in parallel branches of a single circuit instead of in the same branch. But the application of this artifice to the single circuit of the Fleming patent does not convert it into the P N circuit, it merely results in splitting the single circuit of the Fleming patent into two branch circuits which run in parallel to each other between the two terminals of the Fleming device, one carrying the radio-frequency current and the other audio frequency or direct current. The operation of the device is unchanged, it is still a detector, only a detector and no better as a detector. In the P N circuit we have two really distinct circuits, one from the filament to the grid, and one from the filament to the plate; the plate and grid are distinct and separate terminals which as I have pointed out are different in electrical potential and in variations of electrical potential.

Mr. Waterman also states that—

"In the Fleming patent no local battery is employed in the indicating circuit, the only battery being the heating battery. In the P N circuit, a battery B is shown. Such a battery may also be used in the Fleming valve circuit, or the Fleming valve may be used in the P N circuit. My practical use of these valves of the Fleming patent shows that some

of them are very much improved by the use of a battery and that others are not."

What Mr. Waterman does not mention, however, is the important fact that the battery B shown in the P N circuit is absolutely essential to the functioning of the three-electrode tube as such. It is necessary to the functioning of the tube in every circuit in which the tube is employed, for without this battery the three-electrode device could not function as an amplifier, and unless it functioned as an amplifier it would be a practically worthless device. The law of conservation of energy requires a local source of power in any amplifying device.

On the other hand, as Mr. Waterman admits, the Fleming valve does not require such a battery. In fact, it can not use such a battery for it can not amplify. As fully explained in my answer to question 18, a battery called a biasing battery is sometimes employed with detectors such as the crystal detector or Fleming valve and in some cases improves them as detectors. This sensitizing battery is not the same nor does it function the same as the B battery used with the amplifying three-electrode vacuum tube. I have already pointed out the incorrectness of the statement that "the Fleming valve may be used in the P N circuit."

Finally Mr. Waterman contends that in the P N circuit the two functions of impressing the oscillations on the tube [fol. 544] and indicating them have been merely separated into two circuits instead of one as in the Fleming patent. I have explained in detail the functioning of the P N circuit in my answer to question 17: I have shown there that the received oscillations are not indicated in either of the two circuits in the manner of the Fleming device. Variations in grid potential at an audio-frequency rate are produced in the input circuit by the received oscillations. These grid potential variations produce amplified currents through the indicating device. The P N circuit entails both detection and amplification, the former differing widely in essentials from the action of the Fleming valve as a detector and the latter function not exhibited by the Fleming valve at all.

In his drawing "Fleming and De Forest compared," which is Plaintiff's Exhibit No. 107, Mr. Waterman shows the single circuit of the Fleming patent and the P N circuit. Even despite the fact that some minor features such as the filament circuit common to Edison, Fleming, and De Forest

have been over emphasized and some of the major features such as the grid condenser and plate battery of the De Forest circuit have been minimized and despite the fact that no drawing can show the difference in functioning of the two devices, it seems that even a person not skilled in the art would be impressed more with the dissimilarity of the two circuits than with their similarity. Mr. Waterman attempts to explain away these dissimilarities by the following arguments, which I have shown to be contrary to fact:

1. That the grid and plate elements of the De Forest device are a mere splitting up of the single cold element of the Fleming device.

2. That the Fleming valve may be used in the P N circuit.

3. That a battery B like that in the P N circuit can be used in the Fleming valve circuit.

4. That all that is accomplished in the P N circuit is a separation of the detecting and indicating functions of Fleming's arrangement.

The real facts are:

1. The grid and plate elements of the De Forest device are distinct and separate elements connected to different circuits or circuit points, operating at different fixed and varying potentials to produce a mode of operation not possible with the Fleming device.

2. The Fleming valve can not be used in the P N circuit, for a two-terminal device can not fit in a three-terminal circuit; nor can the three-element tube be used in the Fleming circuit, for a three terminal device can not fit in a two terminal circuit.

3. That a battery B, like that in the P N circuit can not be used in the Fleming valve circuit, for the battery B is the adjunct of an amplifying device and the Fleming valve is not an amplifying device.

4. That the P N circuit accomplishes both detection and amplification, the former in a different manner from the detection by the Fleming valve and the latter not exhibited by the Fleming valve at all. Hence it is not true that we have merely separated the detecting and indicating functions of Fleming's arrangement. Nor does either, or both

of the P N circuits perform the function of Fleming's tube and circuit of receiving, rectifying, and passing the rectified pulses of received current through an indicator actuated by the power of the rectified current.

[fol. 545] In my Drawing L I have given circuits illustrating the fallacy of Mr. Waterman's contentions. Figure 1 illustrates the two-element valve in the single circuit of the Fleming patent. The only way the three-element device could be connected in this circuit would be that shown in Figure 2, where the grid and plate electrodes are connected together, and hence operate as one element or the three terminal device is converted into a two terminal device. Used in this way, the two cold elements of the De Forest device are in fact nothing more than a splitting up of Fleming's single cold element and likewise the operation and mode of functioning becomes the same as that of the Fleming valve. The control feature of the grid is lost and with it the amplifying function. Both devices now function the same, both can operate only as rectifiers or detectors. The addition of a biasing battery in either case can only result in a possible increase in sensitiveness as detectors.

In Figure 3 I show the "well-known equivalent" form of circuit which Mr. Waterman considers to be the use of the Fleming valve in the P N circuit. To one not skilled in the art, there might appear to be a similarity between this circuit and the P N circuit shown in Figure 4, though it would be obvious to such a person that considerable changes have been wrought in the original Fleming circuit of Figure 1. However, the circuits of Figure 3 and 4 are not similar and what is still more fundamental, the mode of operation of the two devices in the two circuits are dissimilar. First, relative to the circuits the artifice which has been applied to the simple Fleming circuit is analogous to the series and parallel battery connection which I have discussed before. This artifice merely permits one to take a series circuit in which both high frequency and low frequency or direct currents are flowing and separate the high frequency into one branch and the low frequency or direct current into another branch, these two branches being merely in parallel with each other. The way Figure 3 is drawn, with the low frequency branch to the right of the bulb and the high frequency branch to the left, makes it appear that the separation has been made into two circuits. Figure 3*a* dispels this

illusion: this is the same identical circuit as Figure 3 and shows that the separation has been merely into two branches which are in parallel between the points *a* and *b*. The condenser C' and choke coil L are the features typical of this artifice as I have pointed out before: the condenser C' permits the flow of high frequency currents and stops the flow of low frequency or direct currents; the choke coil L stops the flow of high frequency currents and permits the flow of low frequency or direct currents. In the P X circuit we have two distinct circuits both carrying high frequency currents and low frequency or direct currents. The circuits are distinct and separate because they terminate respectively at the grid and plate terminals which are points having different potentials both steady and varying. Radio-frequency voltage variations are applied to the grid, and, as I have explained before, these variations produce through the action of the grid condenser and leak, low or audio-frequency variations of the grid voltage also. Through the controlling action of the grid, amplified variations of both radio and audio-frequency are produced in the plate current of the tube. The amplified audio-variations affect the indicator I which is a telephone receiver, the radio variations go to waste in this circuit. The funda-[fol. 546] mental thing, the difference in mode of operation of the two devices in the two circuits is this. In the circuits of Figure 1, Figure 3, and Figure 3*a*, the Fleming valve operates just the same to accomplish the same result, viz. the incoming oscillations are rectified and themselves supply the power to actuate the indicator. The device is only a detector and no better as a detector in either circuit, excepting for any possible sensitizing action of the biasing battery in Figures 3 and 3*a* which would be just as effective if such a battery were employed in Figure 1. In the circuit of Figure 4 the incoming oscillations produce, it is true, some feeble rectified current pulses, but only so as to vary the electrostatic potential of the grid electrode. This takes no appreciable power from the received oscillations. There is no indicator for the received oscillations to actuate. The variations in grid potential produce corresponding variations in the plate current which flowing through the indicator produce the response. Thus the detecting action is different in the two devices and the P X circuit, in addition, entails amplification which is a functioning not possessed

by the Fleming valve. To make the operation of the tubes and circuits of Figures 3 and 4 the same we must in Figure 4—

(*a*) Connect grid and plate electrodes together. This immediately destroys the amplifying function of the three-electrode tube and brings the grid electrode to the same instantaneous potential as the plate. The three-terminal device and circuit is now converted to a two terminal device and circuit.

(*b*) Insert a choke coil in series with the indicator unless the indicator itself happens to be a choke for radio-frequency currents. Otherwise the circuit will be inoperative as a detector. In the circuit of Figure 4 no such choking action is required, in fact it is customary to connect a condenser, known as the telephone condenser, in parallel with the indicator to prevent such a choking action.

(*c*) Eliminate the grid leak resistance which now becomes useless even with the highest vacuum tubes, though indispensable in such a case in the P N circuit.

(*d*) Reduce the voltage of the battery from 20 or 40 volts to a few volts or a fraction of a volt for now we have not a "B" battery used for amplification, but a biasing battery used for sensitizing a detector. A voltage as high as twenty or forty volts would practically kill the detector instead of sensitizing it.

Obviously with these changes the P N circuit is the P N circuit no more in substance and in functioning and there is no justification in Mr. Waterman's statement that the Fleming valve may be used in the P N circuit.

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22. Question. Please look at Mr. Waterman's comparison of the amplifier device illustrated in plaintiff's Exhibit No. 85 with the Fleming patent and say whether you agree with Mr. Waterman's comparison.

Answer. The type of apparatus called the audion amplifier discussed by Mr. Waterman in his answer to question [fol. 547] 34 and exemplified by plaintiff's Exhibit No. 85 is known in the art as an audio-frequency amplifier. This particular type of audio-frequency amplifier is one of the

earliest types and utilized the old De Forest three-electrode audion. I have discussed its operation in answer to my question 19 and also the more modern types of audio-frequency amplifiers exemplified by the Navy Type S. E. 1000 and the Signal Corps Type S. C. R. 72 which utilize the modern high vacuum three-electrode tubes. These instruments are used purely and simply to amplify voltages or currents having frequencies ranging from about 400 to 2,000 cycles per second. An input voltage of such a frequency is applied to the input terminals of the amplifier and the output voltage into the telephones is of the same frequency, but is multiplied several hundred times in magnitude. These amplifiers are useful wherever it is desirable to magnify such audio-frequency currents or voltages. Thus the S. C. R. 72 amplifier was used to tap the enemy's telephone communication lines and was also used for ground signalling where the signalling employed alternating currents of a frequency of 500 to 1,000 cycles per second. In radio signalling the currents and voltages which these amplifiers handle have a frequency of about 1,000 cycles per second for radiotelegraphy and a range of frequencies corresponding to that of the human voice or of musical instruments in the case of radiotelephony. When used in connection with radio signalling, some type of detector must be used in advance of the audio-frequency amplifier, the detector acts upon the received radio-frequency currents, which may have a frequency of several hundred thousand or a million per second, and converts these into currents of, say, a thousand per second. These latter currents are then impressed upon the amplifier, which is designed to handle only these low or audio-frequency currents. In the use of Exhibit No. 85 in the United States Navy the separate detector which was used to bring about the conversion in frequency was a crystal detector. Both of plaintiff's witnesses, Graham and Clark, identified this instrument of Exhibit No. 85 as the type of amplifier used by the Navy.

Mr. Waterman, however, apparently had difficulty in finding similarity between this amplifier and the Fleming tube and circuit, for he says little about this amplifier of Exhibit No. 85, but chooses to talk about another old type of instrument, which, to the best of my knowledge, was never employed by the Navy. The circuit diagram of the instrument Mr. Waterman discusses is given in plaintiff's Exhibit No. 110 and also in figure 2 of my drawing G. This is a com-

bination instrument; it combines in one piece of apparatus a detector and an audio-frequency amplifier. Explanatory of this instrument in my answer to question 19, I have called attention to the dash line in my Figure 2 and pointed out that the first tube circuit to the left of the dash line is the typical P–N detector circuit, while the second and third tube circuits to the right of the dash line have the transformers and connections typical of the audio-frequency amplifier. In this instrument, therefore, the conversion of frequency takes place in the first tube, the second and third tubes solely serve to amplify the audio-frequency output of the first or detector tube. The second and third tubes are not detectors but are amplifiers. Having thus changed the discussion to an instrument which contains in one box or case a detector, as well as an amplifier, Mrs. Waterman proceeds [fol. 548] to argue that, therefore, the device as a whole is a detector and leaves the impression, although he does not say so outright, that Exhibit 85, which is an amplifier only, is a detector. Mr. Waterman not only confuses the combined detector and amplifier with Exhibit No. 85, but he also errs in describing the combined instrument. Thus he says:

"Three detector bulbs T^1, T^2, T^3, together constitute the detector."

and later:

"The operation of a tandem series of bulbs is the same substantially as that of a single bulb, that is to say, each successive bulb repeats the action of the one before it. Thus the first bulb T^1 (referring to fig. 88a, reproduced above) detects the receipt of an electric wave."

In this combined detector and amplifier instrument the three bulbs are not detectors, the first bulb only is a detector, the next two are amplifiers. I have already pointed out that the tandem connection of three detectors is an absurdity, a thing not known in the art.

Applied to the amplifier of plaintiff's Exhibit No. 85, which the testimony of plaintiff's witnesses, Graham and Clark, identified as the instrument used by the Navy, Mr. Waterman's statements are completely inapplicable, for none of the three tubes in this instrument is operated as a detector.

The question arises as to why Mr. Waterman introduces this confusion. The answer is, I believe, obvious, viz:

The Fleming valve is a detector and a detector alone.

The three-electrode vacuum tube is an amplifier and Exhibit No. 85 is a clean-cut example of the use of the tube as an amplifier alone.

The same reason probably also explains the fact that Mr. Waterman continually and unnecessarily adds on the word "detector" when he uses the word "amplifier," viz: "I note that Exhibits 72 and 73 are contracts for the supply of amplifiers of this audion detector type," and on page 1922 "the audion amplifier detector," and "the audion amplifier detector were before the court."

Near the end of this answer Mr. Waterman makes the following statement, which appears to be a secondary line of defense provided in case his attempt to make a detector out of an amplifier should fail.

"It should be understood that as a matter of fact not all bulbs, whether they have one cold element as shown in defendant's patent, or two, as in the so-called audion, are able to work efficiently enough to produce an amplification. The bulbs which will amplify have to be selected by trial."

This statement is not in accordance with the facts. The actual facts are:

1. The two-electrode tube of the Fleming patent is not an amplifier and can not amplify.

2. The three-electrode tube with the controlling grid is an amplifier and always amplifies.

These are the facts regardless of the possible quibbles that a smashed, burned-out, or defective three-electrode tube may be inoperative or that a useless laboratory stunt can be performed with a gaseous two-electrode tube.

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[fol. 549] 23. Question. Does paragraph 208 of the Navy Manual of 1915 (plaintiff's Exhibit No. 78) merely refer to a lamp detector and battery, as stated by Mr. Waterman in his answer to question 34 in his 1917 deposition?

Answer. The paragraph 208 of the Navy Manual for 1915, which states "The audion has the further advantage over

the valve in that the telephone can be replaced by the primary of a transformer, the secondary of which is connected to another audion, with the result of amplifying the signals produced (see fig. 88*a*)," is intended to call the attention of the reader to the "result of amplifying the signals" which the audion device possesses and which is not possessed by the valve with or without a battery. It does not refer to a result obtained of the use of the incandescent lamp detector with a battery, as stated by Mr. Waterman, but to a result obtained by the De Forest invention of control by the grid electrode.

This answer of Mr. Waterman, to which reference is made, conveys the impression that a detector when supplied with a battery is capable of amplifying; that it is only necessary to take a detector and add a bettery to it and you have an amplifying device. This is obviously not true, as a plain matter of fact. The best known and most widely used detectors are the various crystal detectors. None of these is capable of amplifying when supplied with a battery. In some cases the addition of a biasing battery will improve the crystal detector as a detector, merely increasing the sensitiveness of the device, but in no case does the addition of a battery make an amplifier out of it. The same is true of the Fleming valve. The addition of a battery to the Fleming valve may or may not improve its sensitiveness as a detector, but it still remains a detector and only a detector. Thus the statement which Mr. Waterman makes that "either the two or the three element bulb can be used to amplify when used with a local battery" is incorrect in so far as it concerns the two-element valve and emphasizes a feature which, while essential to all amplifiers, is not the distinguishing feature of the three-element bulb. The real feature of the three-element bulb which enables it to be used as an amplifier is the grid-control member.

Detection and amplification are fundamentally different operations, and the considerations which determine whether a device is capable of acting as a detector are entirely distinct from and foreign to the considerations which determine whether a device is capable of acting as an amplifier. In the case of the detector the inquiry is: Can the device function to distort radio-frequency oscillations so as to convert them into audio-frequency or direct current? In the case of the amplifier the question is: Can the device when supplied with a given stimulating alternating voltage or

current of high or low frequency function so as to supply a similar alternating voltage or current of the same frequency but of increased power?

The one operation requires distortion, the other requires reproduction and the absence of distortion.

The biasing battery applied to a detector, if effective, increases the distortion which the detector produces, and hence makes it a better detector.

[fol. 550] The battery employed with an amplifier supplies the increased power represented by the undistorted output.

In the case of a detector we are interested in the curvature or rate of bending of the characteristic curve, for, as I have explained in my answer to question 9, it is this feature of the characteristic which determines the distortion, and hence the detecting function of the device.

In the amplifying devices it is desirable to have a minimum of distortion, and therefore a characteristic curve which is as nearly a straight line as possible.

Relative to one type of amplifiers we are interested in the question as to whether the device has a characteristic curve, which runs in the S. E. to N. W. direction or in the S. W. to N. E. direction. If the device has a characteristic with the former slope, then it is a falling characteristic device, and may be an amplifying device by reason of its type of characteristic curve. For faithful reproduction, it is desirable that the characteristic be both falling and straight. Thus the requirements of the detecting function and the amplifying function in these cases where both functions depend upon the type of characteristic curve are clearly dependent upon totally variant essential features of the curves themselves.

Thus the crystal detector and Fleming valve have curved characteristics, and can detect because the characteristics are curved. They cannot amplify, because their characteristics are rising.

The mercury arc and some other devices of this type have falling characteristics, and can amplify because of the falling characteristic. The "soft" two-element tube demonstrated as an oscillation generator before Judge Mayer also was adjusted to the critical gas condition wherein it showed a similar arc characteristic, and therefore might possibly operate as an amplif*y*er by reason of

this gas characteristic, though it has never been so used, and would be no more than a worthless laboratory trick.

The other type of amplifier, to which the three-electrode vacuum tube belongs, is a totally different device. The amplification in these devices depends upon the control feature; that is, the provision of an easily operated control which varies the current of a local source of power. The ordinary telephone transmitter or microphone is an example of this type, for the vibrations of the diaphragm by varying the pressure on a microphonic substance such as carbon vary its resistance, and hence the current flowing through the substance from a local battery. The variations in battery current which are produced represent more power than is required to operate the diaphragm, hence the device is an amplifier. Amplifying devices of this microphone type have been tried out in long-distance wire telephony and as audio-frequency amplifiers in radio signaling, but have been completely superseded by the three-electrode vacuum tube in both uses.

It is true that the same device may operate both as a detector and as an amplifier. This combined functioning is exhibited by the three-electrode vacuum tube in the P N circuit. The distortion which takes place in the grid circuit produces, through the action of the grid condenser and grid leak, audio-frequency variations in the grid potential. This is the detecting operation. These variations in grid potential are faithfully reproduced in the variations of [fol. 551] the plate current resulting from the controlling action of the grid. This is the amplifying operation.

24. Question. Point out the difference in structure and mode of operation between the Fleming valve in a circuit and as shown in the Fleming patent, and the transmitting sets referred to in Mr. Waterman's answer to question 2 of his 1922 deposition.

Answer. I have already pointed out in my answer to question 21 the difference in structure between the Fleming valve and the three-electrode vacuum tube which latter is the device utilized in the transmitting sets referred to in Mr. Waterman's answer to question 2 of his 1922 deposition and of which plaintiff's Exhibit No. 116 purports to represent the circuit diagrams. Briefly the difference is this:

The Fleming valve consists of a heated filament and an insulated plate in a vacuous inclosure and is identical in

structure with the Edison device shown in Patent No. 307031 of October 21, 1884.

The three-electrode vacuum tube contains an additional third electrode in the form of a grid or mesh of wires located between the filament and plate electrodes. As to mode of operation:

The Fleming valve is a detector alone, it acts upon the received signal oscillations and distorts them, thus converting them to audio-frequency or direct current. The three-electrode vacuum tube is an amplifier, and, by reason of this fact, it is likewise an oscillation generator. When supplied with direct current power it is capable in appropriate circuits of generating the high frequency oscillations used in the transmission of radio waves.

The operation of detection and of oscillation generation are, it is true, converse operations. The operations are, however, not reversible, viz., a device which is a detector and therefore capable of converting the received high frequency oscillations over into low or direct current is not for this reason capable of being operated in the reverse sense so as to generate high frequency oscillations when supplied with direct current power. This is a plain matter of fact illustrated by the crystal detectors and Fleming valve detector. These devices are not capable of generating oscillations. Neither the "gas" trick demonstrated before Judge Mayer or the crystal trick demonstrated before the London Physical Society by Doctor Eccles are of sufficient moment to require a qualification of this statement of a well recognized scientific fact. There is, in fact, no connection between the capabilities of detection and of oscillation generation, just as and for the same reasons that there is no connection between the detecting and amplifying properties. There is an intimate connection between the amplifying and oscillation generating properties. A device which is an amplifier is capable of generating oscillations. For an amplifier can in appropriate circuits supply the power to actuate itself and thus operate as an oscillation generator. Perhaps everyone is familiar with the squealing which results in the case of the ordinary telephone instrument, when the receiver is held up in front of and close to the transmitter. This is an illustration of a device which is an amplifier, viz., the telephone transmitter, operating as an oscillation generator (of audio frequencies) when the output circuit (the receiver) is coupled to the

input (transmitter diaphra-m). In this case the coupling is effected by sound waves in the air.

Since the amplifying and oscillating properties are thus intimately connected and interlinked it is not necessary for [fol. 552] me to again take up the explanation as to the fundamental differences in requirements and mode of operation of the detectors and oscillation generators as this is explained at length in my previous answer with regard to amplifiers.

As to the statement of Mr. Waterman that it was demonstrated before Judge Mayer "that the device of the Fleming patent was capable of generating oscillating currents," I contend that this was not demonstrated before Judge Mayer. What was demonstrated was that by reason of a freakish gas action in soft two electrode tubes under critical impractical operating conditions temporary oscillations could be obtained. If this represents the device of the Fleming patent, then the three-electrode vacuum tubes used in the transmitting sets in question have, for this reason alone, nothing in common with the device of the Fleming patent. These tubes have the highest vacuum attainable by modern methods of exhaust and gas or gas action plays absolutely no part in their operation.

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25. Question. Point out the difference in structure and mode of operation between the Fleming valve in a circuit and as shown in the Fleming patent and the receiving sets referred to in Mr. Waterman's answer to question 4 of his 1922 deposition.

Answer. The receivers of plaintiff's Exhibits Nos. 113, 114, and 115 discussed by Mr. Waterman in his answers to questions 4, 5, and 6 of his 1922 deposition are all characterized by the presence of a so-called tickler or feed-back coil marked "j^3" in each of the exhibits. This coil can be used only with the three-electrode vacuum tube and these receiver circuits are known as regenerative receivers. I have already explained the operation of these receivers and pointed out that these circuits enable the operator to obtain signals twenty or thirty times louder than can be obtained by the use of the ordinary P N circuit by reason of the fact that the amplifying property of the three-electrode vacuum tube is more completely utilized; the amplified radio frequency currents discarded in the P N circuit

are here utilized through the medium of the ticker or feed-back coil. It is impossible to utilize these circuits with any other form of detector, since none of these devices are amplifying devices. Excepting for the great improvement in response made possible by regeneration, which depends solely upon the amplifying property of the three-electrode vacuum tube, the feed-back coil would be absent and the crystal detector would have been the detector used in these receivers, for even the three-electrode vacuum tube in the ordinary P X circuit gives a response only some 50 per cent better than a good crystal detector. The output of the crystal would, then, be amplified using the three-electrode vacuum tube amplifiers. This in fact was the method of reception primarily used in the Navy before the advent of the regenerative receiver.

The Fleming valve has been of no importance in the radio art in the Navy or elsewhere. Being only a detector, a detector inferior to the crystal and also less convenient and [fol. 553] more costly, the crystal has been and always would be used in preference. It is the amplifying property of the three-electrode vacuum tube which has enabled it to replace the crystal and which is the reason for the existence of these regenerative type receivers. Throughout the whole radio art the use of vacuum tubes is predicated entirely upon the amplifying property possessed only by the three-electrode vacuum tube.

In any of these receivers, by increasing the coupling between the feed-back coil j^3 and the coil j^2 which is in the input circuit of the vacuum tube, oscillations can be obtained and the receivers can then be utilized for the reception of continuous waves by the beat note method. The oscillating property is dependent on the amplifying property, hence this method of reception basically depends upon the amplifying property of the three-electrode vacuum tube and is not possible with either the crystal detector or Fleming valve.

The amplifying property of the three-electrode vacuum tube has in fact revolutionized the radio art.

26. Question. What have you to say as to whether the operation of the three-electrode device with respect to amplification is obscure, as stated by Mr. Waterman in his 1917 deposition (q. 31)?

Answer. Relative to the Fleming valve, Mr. Waterman states in his answer to question 31 that—

"Why the device operates in the manner set forth in the patent, or what the particular mechanism of the space within the bulb may be which secures the result, is not certainly or clearly understood, but Fleming sets forth the construction and the apparent functioning of the apparatus in the above statement."

In this I do not agree with Mr. Waterman. In fact, the mechanism of the space within the bulb was clearly understood prior to the date of the Fleming patent. It was known as early as 1899 by the work of the eminent physicist, J. J. Thompson, that the incandescent filament is a source of electrons or of those minute negative electrical charges which seem to be at the basis of all physical phenomena. In fact, in 1903 O. W. Richardson derived mathematically the famous law relating rate of emission of these electrons from a heated filament to the temperature of the filament, a law based purely on physical reasoning. This law is accepted to-day and is known as Richardson's law. Before 1904 the mass and electrical charge of an electron had been determined and its behavior under the action of electrical forces was well understood. In fact, the knowledge of the physicists with regard to the electron had progressed to an extent that in 1903 they were concerned with such matters as the manner in which the apparent mass of an electron varied with its velocity of motion when this velocity approached that of the velocity of light, the transverse and longitudinal mass of such a moving electron, whether the apparent mass of an electron is entirely due to its electrical charge, etc. In 1903 the well-known experiment of Kaufmann was published. This experiment proved that the inertia or mass of an electron is entirely due to its electrical charge. Thus the mechanism which caused the curious unilateral conductivity between a filament and cold plate which was observed by Edison in 1883, and which, at that time was a curiosity, had been completely explained even prior to 1904.

Again, in his answer to question 33, Mr. Waterman states relative to the three-electrode vacuum tube that—

"The precise details of the operation of these vacuum valves are not fully understood, and my statements are therefore to be regarded as a general indication of what [fol. 554] happens rather than a precise definition of the way it happens."

There is nothing concerning the operation of these tubes which is not fully understood. In fact, the operations are so well understood that the mathematical formulas and laws of operation have been worked out and are given in numerous standard treatises. A mere glance at Doctor Van der Bijl's book on The Thermionic Vacuum Tube or the German publication by Dr. Hans G. Moller on The Electron Tubes or any other of the numerous standard treatises is sufficient to dispel any illusion that the operation of these devices is not completely understood. In these books are found complete explanations in words and by diagrams of the operation of the three-electrode vacuum tube as a detector, amplifier, and oscillator together with the mathematical treatment which gives the laws of operation. In Doctor Van der Bijl's book will be found the mathematical laws which permit the tubes to be designed to have definite constants and the experimental methods employed in determining these constants. Knowing the constants of the tubes and of the circuits one can predict in advance the amplification which will be secured with an amplifier whether or not a tube will generate oscillations in a given circuit and, in fact, all of the results which can be obtained. These operations would not be subject to mathematical calculation if the operation were not thoroughly and completely understood.

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27. Question. Has the two-element device as disclosed by Fleming gone into any considerable use in the radio art?

Answer. The Fleming valve has never occupied a position of even slight importance in the radio art. It has never been used as a radio detector excepting in a few scattered instances. The reason for this is very simple; the device is not a good detector, and the art has had other simple devices which were better detectors, such as the electrolytic and crystal detectors. The latter was the universal detector used in the past and, in feat, is in very extensive use to-day. The three-electrode vacuum tube has displaced the crystal as a detector, not because the detecting property alone of this tube is superior to the crystal, but because it combines amplification and detection and gives better results because of the amplification, in particular, in the regenerative circuits where the amplification is more fully utilized. Also because of the amplification feature, the

three-electrode tube can be used as a combined detector and oscillation generator for the reception of continuous or unmodulated waves. The other uses of the three-electrode vacuum tube as a straight amplifier and as an oscillation generator for transmission purposes—uses which are of extreme importance in the radio arc—do not concern detection at all. At the present day the art could absolutely forego the use of the three-electrode tube as a detector without suffering a whit; the crystal could be employed wherever detection is required without any sacrifice whatsoever. If, however, the art were compelled to sacrifice the amplification feature of the three-electrode vacuum tube, it would be demoralized.

[fol. 555] That the Fleming valve is relatively poor as a detector is well recognized in the art. Evidence in this regard is given by Mr. Clark, plaintiff's witness. Mr. Clark testified both in this case and in the De Forest case as to experimental comparisons which he made of the sensitiveness of the Fleming valve furnished to the Navy by the Marconi Co., with some sample direction-finder apparatus and the sensitiveness of crystal detectors. He is evidently hazy as to the date when these comparisons were made, for in the De Forest case he gives the date as 1913 or 1914 and in this case as 1910 or 1911, but in answer to recross-question 45 identifies them as the same. Evidently his recollection of the results which he obtained are likewise hazy. Thus in answer to redirect-question 38 he states:

"The two-element valve was of the same general order of sensitiveness as the crystal.

"I recall that the valve was, of the two, the more sensitive. Possibly it was twice as sensitive."

And later in recross-question 47, after describing one test relating to the direction finder itself, states:

"A second subsidiary test was to try the efficiency of the detector supplied with the direction finder, namely, the two-element valve, with the standard detector in the Navy at that time, and that test, while related to the main test, was also a separate and complete test of its own."

I have looked up Mr. Clark's official report to the Navy Department on these tests. This report was entitled "Bellini-Tosi Direction Finder Tests" and dated October

5, 1915, the experimental work being done in 1914 as stated on page 4 of the report. I find that Mr. Clark compared the sensitiveness of both the insensitive carborundum detector and Fleming valve supplied by the Marconi Co., with the standard Navy detector, the galena crystal. The following were his experimental results as to the audibility of the same signal with the three detectors as given on sheet 8 of the report: Carborundum detector, audibility 80; Fleming valve, audibility 160; Galena crystal, audibility 400. So that we find the standard Navy crystal detector to be three and one-half times superior to the Fleming valve instead of the Fleming valve being twice as sensitive, as one would gather from Mr. Clark's testimony. These experimental results are followed in the report by the following short significant statement:

"After the first few tests on the direction finder, the galena detector was used for all tests."

Mr. Clark's procedure represents that of the art. The report concludes with "Recommendations," of which the second is interesting, viz:

"2. Replace carborundum detector and Fleming valve by more sensitive crystal detector (as galena or silicon-arsenic) and De Forest audion amplifier. Possibly it would be sufficient to supply binding posts for this, and use the detectors available at the station of use."

In passing it might be noted that the Fleming valve as tested by Mr. Clark was provided with the biasing battery voltage to which Mr. Waterman has referred at various times.

In further confirmation of the standing of the Fleming valve in the radio art the following are a few references taken from the literature.

[fol. 556] Relative to the Fleming valve as a detector the Navy Manuals for 1915, page 143, and 1918, page 159, stated tersely:

"It is not found to be a very sensitive one."

The 1915 Manual states, on page 139:

"There is but one type of detector now in general use, viz, the crystal or rectifying detector."

In the 1918 Manual this statement is revised so as to read (p. 156):

"There are two types of detectors now in general use, viz, the audion, and the crystal, or rectifying detector."

In Doctor Van Der Bijl's book is found, on page XV of the introduction:

"As a detector of electro-magnetic waves, the valve has no commercial value. The device which is used for detecting purposes is the three-electrode tube which in addition to the anode and hot cathode, also contains a grid to control the flow of electrons from cathode to anode. The grid was inserted by De Forest in 1907, who called the device the "audion" and it is the insertion of the grid which has made the termionic tube of such great value."

On page 112 of the same book I find:

"By our present standard of measurement the two electrode tube is a very inefficient detector "

And also the book Wireless Telegraphy, by Leggett, previously referred to, which says, on page 112:

"4. Contact detectors: These are the detectors most used at the present day. They consist essentially of contact points between a suitable metal and crystal such as molybdenite or gelana. * * * These detectors are the most sensitive for ordinary working, can not be greatly damaged, are always ready for use, and require no auxiliary apparatus. They are therefore very widely used."

And on page 161:

"As a detector the Fleming valve was fairly sensitive, but from the author's own personal experience, a result also noticed by Stanley, it was not so sensitive as a crystal detector. As well as being more sensitive, the crystal detector has the advantage of not requiring any heating battery, with consequent adjustment and maintenance troubles."

Also I find in the book Wireless Telegraphy, by L. B. Turner, published 1921 by the Cambridge University Press, London, on page 88:

"The introduction of the grid was the work of L. de Forest in 1907, and although the rationale of the triode does not appear to have been fully understood at the time, and its uses have only recently been developed, this addition to the Fleming valve marks the conversion of the thermionic tube from a mild convenience into the potent and indispensable instrument it is to-day."

And in the book Guide to the Study of the Ionic Valve, by Owen, published by Isaac Pitman & Sons, England, in 1919, on page 19:

"The two-electrode valve is now obsolete except in a modified form called the 'kenetron' to which reference is made later on. It was abandoned in favor of carborundum, which is more sensitive and requires less auxiliary apparatus. By the introduction of a third electrode into the valve between the filament and plate, Dr. Lee de Forest, of New Y..k, made use of an entirely different principle."

[fol. 557] I could multiply such statements in the literature of the art, but will conclude with two experimental papers on the relative sensitiveness of these detectors. In a paper by P. R. Coursey in the proceedings of the Physical Society of London for February, 1914, page 102, a comparison is made of a great number of well-known detectors as to their relative sensitiveness. This work, I believe, was done in Professor Fleming's laboratory. The results were expressed in terms of the sensitiveness of the Marconi magnetic detector, assumed to be unity. It is well known that this detector is one of the less sensiti‑ detectors. On this basis the well-known perikon crystal detector was found to be twelve times as sensitive, the galena plumbago crystal detector nearly thirteen times, and a number of other well-known crystal detectors varying between these figures. Three samples of Fleming valves were also investigated, two of which were found to be only equal in sensitiveness to the Marconi magnetic detector. One, however, was found to be the equal of the perikon. In a bulletin from the Bureau of Standards, volume 6, No. 4, page 527, is a paper by Dr. L. W. Austin on the comparative sensitiveness of some common detectors of electrical oscillations. In this paper Doctor Austin finds the Fleming vacuum valve detector to be inferior to the perikon crystal detector in the ratio of two to ten times.

It is also a matter of fact that the radio art has not used the Fleming valve to an appreciable extent. The United States Navy has been the largest user of radio apparatus in this country and has never employed the Fleming valve. This accords with the testimony of Mr. Clark who in his answer to question 1 claims to be familiar with every type of set, both transmitting and receiving that the Navy obtained between the dates 1908 and 1919 and who states in his answer to recross-question 44 that the only Fleming valves he ever tested were those on the direction finder set referred to above. I have been generally familiar with Navy apparatus since about 1912 and been seen and operated practically all of their receiving apparatus but have never seen or heard of the Navy employing the Fleming valve. I also have been generally familiar with the apparatus used by others in this country and to some extent abroad and know of no case where the Fleming valve was employed in such apparatus. The Fleming value receiver, which is Plaintiff's Exhibit No. 28 and which was described by Mr. Waterman in question 36, immediately succeeding his description of the Navy three-electrode apparatus, was not to my knowledge ever employed by the Navy. It appears from the record (Brennen, q. 53 to q. 61) that a single receiver of this type was shipped to a Marconi employee and addressed to the U. S. S. *Louisiana* at the Norfolk Navy Yard, but it does not appear from the record that this receiver was intended for or used by the Navy. This receiver was shipped presumably on October 25, and was received back again by the Marconi Co. on October 31, 1910. I am quite sure that no receiver like this was used by the Navy.

It also appears that receivers employing the Fleming valve were rare even in the case of the Marconi Co. itself. I have compiled a list of the various receivers put out by the Marconi Co., from the book Practical Wireless Telegraphy, written by Elmer E. Bucher, instructing engineer, Marconi Wireless Telegraph Co. of America, and published in 1917. I find only one mention of a receiver utilizing the Fleming valve. This occurs on page 143, and the statement reads: [fol. 558] "The diagram Figure 162 shows the fundamental circuit of the widely used Marconi-Fleming valve receiver."

Immediately following this statement I find, on page 144:

"The American Marconi Co. has developed a crystal holder to fit in the Fleming valve socket, as shown in Figure 163."

Also I find on page 144 that the Marconi Type 107 A tuner (American Marconi Co.), which is a redesign of the above tuner, does not employ the Fleming valve, but (p. 145) "is designed for the carborundum detector, an extra set of posts is provided for an additional crystal such as cerusite."

The other receivers mentioned in this publication are the following:

Page 148. Marconi multiple tuner (English Marconi Co.). Uses magnetic detector.

Page 151. Marconi type 106 receiving tuner (American Marconi Co.). Uses crystal detector.

Page 154. Marconi receiving tuner, type 101 (American Marconi Co.). Uses cerusite and carborundum crystal detectors.

Page 157. Marconi Universal receiving set (English Marconi Co.). Uses crystal rectifiers as carborundum, zincite, bornite, etc.

Page 172. Marconi balanced crystal receiver. (English Marconi Co.)

Page 174. Type 112 receiving tuner (American Marconi Co.). Uses carborundum detector.

The type 106 receiving tuner using a crystal detector is also described in 1916 by Harry Shoemaker, research engineer of American Marconi Co., in an art-cle in the Proceedings of the Institute of Radio Engineers, August, 1916. The article is entitled "Recent standard radio sets."

It is a fact well known and recognized by all radio engineers that the Fleming valve has never occupied a position of even slight importance in the radio art.

28. Question. Please refer briefly to the prior art and say whether it was obvious prior to 1904 that the Edison bulb would act as a rectifier at all frequencies?

Answer. As early as 1883, Thomas A. Edison discovered the device which is the forerunner of all the so-called thermionic devices which have become so extremely important in telephone and radio communication. Edison inserted a metal electrode inside the bulb of an incandescent lamp and provided a circuit connecting the metal plate and the incandescent filament. He inserted a galvanometer

in this circuit and discovered that electrical currents could flow through the vacuum between the incandescent filament and the plate. If the metal plate were connected externally through the galvonometer to the positive terminal of the filament, the galvonometer would indicate a current, if the external connection were made to the negative terminal of the filament then no appreciable current would flow. At this time the mechanism underlying Edison's discovery was completely unknown, and the phenomenon was mystifying. It was called the "Edison effect." In 1884 Edison obtained a patent on his device, utilizing it as a means of controlling the voltage supply for incandescent lamps.

The discovery of Edison aroused considerable interest and numerous investigators continued experiments upon the Edison effect. Among these were Prof. Edwin J. Houston, who gave a paper in 1884 before the American Institute of Electrical Engineers, and Sir William Preece, [fol. 559] who in 1885 published a paper in the London Electrician on experiments which he made on lamps which were furnished to him by Edison. Professor Fleming was one of the investigators and published a number of papers on the Edison effect. In 1890 in the Proceedings of the Royal Society, volume 47, 1890, he pointed out the unilateral conductivity of the space between the filament and plate and the possibility of rectifying alternating current. Thus he states in this paper:

"When the lamp is actuated by an alternating current a continuous current is found flowing through a galvanometer, connected between the insulated plate and either terminal of the lamp.

"The vacuous space between the middle plate and the hot negative leg of the carbon possesses, however, a curious unilateral conductivity. * * * The cell is thus able to force a current through the vacuous space when the direction of the cell is such as to cause negative electricity to flow across the vacuous space from the hot carbon to the cooler metal plate, but not in the reverse direction."

In 1897 in the discussion of a paper on the Edison effect by Howell before the American Institute of Electrical Engineers (Trans. Amer. Inst. Elec. Eng. vol. 14, pp. 42, 43), Dr. A. E. Kennelly says:

"It has long been known that the passage of a continuous current through a Geissen tube sets up a series of pulsatory currents or discharges which are capable of producing alternating currents in a separate circuit through the intermediary of an alternating current transformer. So far as I know, however, it has been pointed out for the first time in this paper that an alternating current passed through an incandescent lamp, giving the 'Edison effect' is capable of producing in a branch circuit through a third wire in a lamp, continuous or at least unidirectional currents. Consequently it is interesting to observe that a vacuum tube, in the broadest sense of the term, is capable of supplying not only alternating currents from continuous currents, but also continuous currents from alternating currents."

Doctor Wehnelt, who worked with special type of filament similar to that which is extensively used in thermionic devices to-day, the so-called oxide-coated filament, also showed in October, 1904, that the Edison device could be used to rectify alternating currents. In his article in the Physikalische Zeitschrift, under date of October 20, 1904, Wehnelt says:

"If, therefore, we connect the electrodes A and K with an alternating source of current, then the tube acts as an electric valve in that it allows to pass through only one phase of the alternating current. The tube (fig. 4) can consequently serve for the purpose of transforming alternating current into pulsating direct current."

Thus prior to the date of application for the Fleming patent, which I am advised was November 16, 1904 (British application), the two-electrode valve was well known among engineers as a rectifier of alternating currents.

During the decade prior to this date there was also taking place a tremendous revolution in the knowledge of mankind with respect to physics and the laws of physics. During this period the electron theory was born and proven to be fundamental in all branches of physical theory and in fact in the construction of matter itself. The electron theory explained and correlated the phenomena in all branches of physical science and incidentally completely [fol. 580] explained the mechanism underlying the Edison effect. Thus in 1899 in a paper in the Philosophical Magazine, volume 48, page 547, J. J. Thomson, the most promi-

nent worker in these exciting times, showed that the Edison effect was due to the emission of negative electrons from a heated filament and identified them with the electrons which were fundamental in physical phenomena in the whole domain of physics. This work was followed by a complete explanation by O. W. Richardson as to the mechanism of the emission of the electrons from the heated filament, published in two papers—Proc. Camb. Phil. Soc., volume 11, page 286, 1901, and Phil. Trans. Roy. Soc., volume 11, page 497, 1903. In the latter paper, Richardson derived the law of emission of the electrons, that is a relation between the number of electrons emitted per second and the temperature, a law well known as Richardson's law. The characteristic of electrons which identified them in optical and electrical phenomena as being fundamental in all physical phenomena was the ratio of the charge to the mass or quantity, known as $\frac{e}{m}$. This quantity had been determined in numerous ways in connection with various phenomena and was found to be the same in all. Its value for an electron is about two thousands times as great as the same quantity for a hydrogen ion in electrolysis. Hence, either the charge of an electron must be two thousand times greater than the charge of the hydrogen ion or the mass of an election must be only one two-thousandth of that of a hydrogen atom. Various phenomena tended to prove that the latter was the case. In the period between 1897 and 1903, the matter was definitely settled by five separate experimental determinations of the actual electrical charge carried by an electron. This charge was shown to be identical with that of the hydrogen ion and hence the mass of an electron is about one two-thousandth of that of a hydrogen atom. This work was published as follows:

Townsend, Proc. Camb. Phil. Soc. IX, p. 244, 1897.
Wilson, C. T. R., Proc. Camb. Phil. Soc. IX, page 333, 1897.
Thomson, J. J., Phil. Mag. XLVI, page 528, 1898.
Thomson, J. J., Phil. Mag. V, page 354, 1903.
Wilson, H. A., Phil. Mag. V, page 429, 1903.

Thus in the years immediately prior to 1904 it had been established—

1. That the incandescent filament of Edison served to emit electrons.

2. The mass of these electrons were only a two-thousandth of that of a hydrogen atom.

These facts would be known to any scientist of that day, for the subject was at the forefront of scientific interest. Therefore any scientist could have predicted in 1904 that the Edison device, a known rectifier for alternating currents, would operate just the same at radio-frequencies.

I will quote again the answer of E. H. Armstrong, expert on behalf of the Fleming patent in the case in New York, in explaining the operation of the three-electrode tube.

"74. Cross-question. Can you give some brief explanation of why you and other scientists make this assumption that in devices of the vacuum type using electron discharges they would operate under both high and low frequencies in exactly the same way, other conditions being equal?
[fol. 561] Answer. The mass of the electron is so very small, and the speed so enormously high, that the device is practically without inertia, and we would expect for all frequencies within reason, or certainly all frequencies such as used in radio telegraphy, the operation would be the same."

This statement, accurate when made, was just as accurate in 1903, and any scientist at that date would have known it from his reading of the literature of the art. Indeed he would have had no reason to think otherwise.

The further question remains as to whether the use of rectifier as a radio detector was known to the art prior to 1904. The use of a rectifier as a radio detector was pointed out with extreme clarity in a French patent No. 328687, to M. Gillet de Valbreuze, dated May 7, 1903. In fact, Figure 2 of the Valbreuze patent is identical with Figure 2 of the Fleming patent. The rectifier which Valbreuze utilized was the well-known sphere and point rectifier. His Figure 2 shows two such rectifiers in parallel so arranged as to utilize both alternations of the wave, which is exactly the arrangement shown by Fleming in his Figure 2 and for the same purpose. The indicating

device shown by Valbreuze is a relay with two differential windings; that shown by Fleming is a galvanometer with two differential windings. In both cases the rectified currents supplied by the two rectifiers are additive in their effect upon the indicating device. It is doubtless true that the Valbreuze type of rectifier is even less sensitive than the Fleming type, but the use of a rectifier as a detector is clearly disclosed. In my drawing M, I show for comparison, the corresponding figures from the two patents. I have turned the Fleming figure on its side in order to make it correspond in arrangement with the Valbreuze diagram and have eliminated many of the letters used as symbols in the Fleming figure because they confuse the circuit diagram. The sphere in the Valbreuze rectifier corresponds to the plate of the Fleming device, the point of Valbreuze to the filament of Fleming. I have also shown the antenna omitted in this Fleming figure, as it is shown in Fleming's Figure 1.

The following is a translation of claim 2 of the Valbreuze patent:

"2. The use of a device called an electric valve formed by a vacuum tube, or of several similar valves combined together in order to transform into currents always in the same direction, the alternating currents of very rapid frequency transmitted to the receiving apparatus."

Thus I find the following to be the facts regarding the history of the Edison device and the art prior to 1904.

1. The Edison device was well known as a rectifier of alternating currents.

2. In the years just prior to 1904, it was shown that the incandescent filament was an emitter of electrons and that electrons had unappreciable inertia, so that any scientist could predict that the Edison device would operate the same regardless of the frequency.

3. In 1903 the use of the re-tifier as a detector of wireless waves was clearly disclosed.

The mystery surrounding the Edison effect had been completely dispelled and the whole mechanism explained during the years just prior to 1904, a period which was revolutionary in the whole domain of physics. Instead of there

being a distinct lapse in time between the earlier work [fol. 562] on the Edison effect and the Flemington use of this "curiosity" the fact is that the progress of scientific knowledge had completely bared the innermost mechanism of the Edison effect and made it possible for any scientist to predict that the device would operate as it was operated by Fleming. It was, therefore, incorrect as a matter of fact to say that "at the date of Fleming's application it was not known to men skilled in the radio art that a rectifier would act as a detector or that anything that would rectify oscillations of a low frequency could rectify waves of the order used in radio communication."

As a matter of fact:

1. It was known to men skilled in the art at the date of Fleming's application that a rectifier would act as a detector.

2. One skilled in the art at the date of Fleming's application would have understood the complete mechanism of the Edison effect and would have been able to predict that the Edison device would rectify waves of the order used in radio communication. Such a prediction would be based on the facts discovered prior to Fleming.

* * * * * * *

29. Question. In connection with your testimony regarding the ultra audion, I neglected to call your attention to the testimony of Mr. Waterman in his answer to question 33 (p. 526), where he refers to the device continually detecting the fact that it is detecting. Will you say if you agree with this testimony?

Answer. The statement to which reference is made reads:

"Any detector which is also able to control the local battery current so as to amplify the received energy is capable of being put in the oscillating condition, this being done by transferring part of the energy of the battery circuit back to the controlling circuit, to keep the latter continuously excited. In other words, the continuous repetition of the detecting function is the so-called oscillating state and a detector in the oscillating state may be said to be continuously detecting the fact that it is detecting."

This is another confused statement which attempts to connect up the detecting function of the Fleming valve with the functioning of which it is not capable, viz, amplification. The use of the term "detector" in the first sentence is gratuitous and superfluous. The matter of detection is not pertinent—a device which can amplify can be put in the oscillating condition, a device which can not amplify can not be put in the oscillating condition. The detectors such as the crystal and Fleming valve, which are not amplifiers, can not generate oscillations; the three-electrode vacuum tube and other amplifying devices can generate oscillations regardless of the fact as to whether or not they can be used as detectors. This first sentence would become a more sensible expression of fact if it were revised to read:

"Any device which is able to control a local battery current so as to amplify the input energy is capable of being put in the oscillating condition, this being done by transferring part of the energy of the battery circuit back to [fol. 563] the controlling circuit, to keep the latter continuously excited."

The second sentence of Mr. Waterman's statement is to me devoid of sense or meaning. I do not understand what is meant by a detector "detecting the fact that it is detecting."

In comparison with this confused statement of Mr. Waterman, I would like to quote a statement on the same subject matter by Doctor Van Der Bijl, taken from page 266 of his book, already referred to:

"Since the three-electrode tube can operate as an amplifier, the energy in the output circuit is greater than that in the input circuit. Hence, if part of the energy in the output be returned to the input, there will be a further amplification of energy resulting in an increased output. If the amplified energy gets back to the input in sufficient amount, and if the phase relations of the output and input currents are right, there will be a constant reamplification and feeding back of energy from the output to the input, and the device will then produce sustained oscillations without it being necessary to supply potential variations to the grid by external means. In other words, the device will then operate as an oscillation generator."

It will be noted that Doctor Van Der Bijl does not find it necessary to introduce the terms "detector" or "detection" in any phase of his discussion, nor does he say anything about "detecting the fact that it is detecting." Anyone at all familiar with such devices knows that there is no connection whatsoever between the detecting function and the functions of amplifying or oscillating.

30. Q. You have referred to the use of the S. C. R. 72 amplifier in ground signaling. Will you explain more fully this use of vacuum tubes?

Answer. Ground signaling was a method of communication extensively employed in the war.

This method of signaling used only audio-frequency currents transmitted through the ground. In the reception of these signals, the S. C. R. 72 audio-frequency amplifier was employed. This amplifier utilizes three-electrode vacuum tubes. The method of signaling and the apparatus employed are thoroughly described in a Signal Corps pamphlet entitled "Ground Telegraphy, or T. P. S." This pamphlet was a confidential publication during the war, but has since been released. The method is described on pages 3 and 4, as follows:

"Ground Telegraphy, or T. P. S. (from the French 'telegraphie par sol') is a means of communication which requires no wire connection between the sending and receiving stations, but it is different from radio telegraphy in that it involves the use of pulsating or alternating currents of comparatively low frequency (600 to 1,800 cycles per second) instead of oscillations of high frequency, of the order of 100,000 to two or three million cycles per second. Also, the transfer of electrical energy from the transmitting to the receiving apparatus take place by induction and conduction through the ground, instead of through the air, as with radio.

"The principles on which the theory of this means of communication are based are quite simple. They are illustrated in Figure 1. A generator A (alternator or buzzer) producing an audio-frequency high voltage alternating or pulsating current is connected to the ground by means of two wires, AB and AC, which are grounded at points B [fol. 564] and C. These two grounds are 50 yards to 200 yards apart. The circuit followed by the current generated at A is then made up by the two wires AB and AC and by

the conducting ground between B and C. Since the ground is a fair conductor of electricity, the electric current will not be concentrated on the straight line BC, but it will follow a great number of paths through the ground, called lines of current flow, and represented schematically in Figure 1 by the dotted lines. These lines of current flow may, under suitable geological conditions of the ground, spread out as far as 2 or 3 miles away from the sending circuit ABC.

"If now at a certain distance from the sending circuit ABC a metal wire is grounded at two points D and E, the current from A will not flow through the ground between points D and E along the corresponding line of current flow. Instead, it will flow through the wire DFE, which is a low resistance path shunting the line of current flow DE in the ground. A suitable instrument F inserted in series with the wire DE may therefore be employed to utilize this current in signaling work. The current in the circuit DFE is extremely small due to the rather high resistance of the ground and to the fact that the current generated by A spreads over such a considerable area that the wire DE picks up only a very small portion of the total current flowing through the ground in the various paths between B and C. The instrument F must therefore be very sensitive. It is usually a telephone receiver.

"In most cases, the current in the wire DE is even too faint to produce a sound in a telephone receiver directly inserted in series with the wire. This has made it necessary to use amplifying devices, which amplify the currents received."

(For convenience I insert a copy of Fig. 1 opposite.)

On pages 5 to 8 the transmitter is described (quoting from page 5):

"The T. P. S. transmitting set, type SCR-71, consists of a power buzzer, used for generating a high-voltage, audio-frequency, pulsating current."

On page 7 the range of frequencies generated by this transmitter is stated to be variable from 650 to 1,750 cycles per second.

The receiving set is described on pages 8 to 12, of which I quote the following (pp. 8-9):

"The T. P. S. receiving set, type SCR-72, is a low-frequency amplifier, consisting of a vacuum-tube amplifier with the necessary storage batteries and telephone receivers and a ground equipment similar to that of the SCR-71 transmitting set. A complete parts list is given at the end of this pamphlet.

"The amplifier consists of two type VT-1 three-electrode vacuum tubes connected for cascade amplification, and making possible the use of either one or two stages of amplification. As shown on the circuit diagrams, Figure 6, the T. P. S. current to be amplified is made to flow through the primary winding of an iron core input transformer, by connecting the two grounded receiving line wires to the binding posts of the amplifier box marked 'T. P. S.' The secondary of this input transformer is connected between the filament and the grid of the first vacuum tube. The plate circuit of this tube comprises a 22-volt, type BA-2 dry battery connected in series with the primary of an iron core transformer which couples the plate circuit of the first tube to the grid circuit of the second tube. The secondary winding of this coupling transformer is [fol. 565] connected between the grid and the filament of the second tube, while a type BA-2 dry battery furnishes the plate current."

(Page 9):

"This amplifier is not limited in its use to the reception of T. P. S. signals. It may also be used to amplify damped or modulated radio signals after they have been detected (rectified). For this purpose, the entire primary winding of the input transformer is used, the corresponding terminals on the amplifier box being marked 'Radio.' These terminals are connected to the telephone terminals or plug of the radio receiving set used in the reception of the radio signals it is desired to amplify. This inserts the amplifier in the audio-frequency circuit of the radio receiving set."

On page 11 is given a wiring diagram (fig. 6) which is essentially the same as the diagram of the Navy S. E. 1,000 amplifier, which is Figure 1 of my drawing G. From this figure it is seen that the only difference in the circuit when connection is made to the "Radio" binding posts instead of the "T. P. S." binding posts is that all of the primary turns of the input transformer are used instead of a por-

tion of them. This is merely a matter of fitting the amplifier to the circuit in which it is being used, the circuits being lower in resistance in the T. P. S. work than in the radio work and hence permitting the use of a higher step-up ratio in the transformer. In both cases only audio-fr quency currents actuate the amplifier.

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31. Question. In your answer to question 12 you referred to having made certain tests to demonstrate the correctness of your testimony to the effect that such oscillations as were obtained before Judge Mayer were due to the gas characteristic. Are you ready and willing to repeat these tests in the presence of counsel for the claimant, if so requested?

Answer. I am.

(At this point counsel for the defendant reads upon the record the following letter, which was sent on the date given in the letter, to claimant's counsel:)

Marconi v. U. S. No. 33642

February 14, 1923.

Messrs. Sheffield & Betts,
52 William St., New York City.

"Gentlemen: Upon receiving from the commissioner the minutes of Mr. Waterman's deposition, we note the addition of a statement by him to the effect that it is possible to reproduce the two-element bulbs used in the demonstration made before Judge Mayer, if sufficient time is allowed to ascertain the dimensions of the bulbs from old records and to obtain the necessary materials.

We would like to procure some of these bulbs, and if the Marconi Company is willing to reproduce them we would like to know how soon we may expect to receive them.

Yours very truly, C. V. Edwards (Signed).

[fol. 566] 32. Question. In your testimony you have referred to the S. E. 1000 amplifier. Can you produce one of these devices?

Answer. The device which I here produce is one of these amplifiers.

(The device produced by the witness, together with the tubes therein, is offered in evidence and marked "Defendant's Exhibit E.")

33. Question. Can you produce samples of some of the three-element tubes?

Answer. I have here three samples taken at random. One is a small VT-1 tube used for receiving purposes. Another is a small VT-2 tube used for transmitting purposes. I also have here a type P Pliotron, which is a fairly high power tube used for transmitting purposes. I think this latter tube particularly emphasizes the fact that the grid is not in any sense a mere subdivision of the plate element. In this device the plate is in fact in two parts, both of which are however, connected together and connected to one terminal. These are the heavy outside plates. Between these plates is a substantial frame upon which the light grid wire is wound. Within the grid is located the M-shaped filament. I might note that the practice of dividing the plate into two large outside plates connected together is quite common. This is the case with respect to the VT-1 and VT-2 tubes. I believe that all of these tubes show that the grid element is in no sense a part of or subdivision of the plate element.

(The tubes produced by the witness are offered in evidence and marked, respectively, "Defendant's Exhibit F, VT-1 Tube;" "Defendant's Exhibit G, VT-2 Tube;" "Defendant's Exhibit H, Type P Pliotron.")

(Defendant's counsel offers in evidence the following drawings, patents, and publications referred to by the witness, the same being marked as follows:)

I. Miller drawings, A to M, inclusive.

J. U. S. Patent No. 307031, granted October 21, 1884 to Edison.

K. U. S. Patent No. 879532, granted Feb. 18. 1909, to De Forest.

L. The Thermionic Tube, by Van der Bijl, published at New York, 1920, pages XV, XVI and XVII, and pages 42, 108, 112, 266 and 271.

M. Proceedings of the London Physical Society, 1910, vol. 22, pages 360-363, inclusive. (Article by Eccles.)

N. Wireless Telegraphy, by D. Leggett, London, 1921, pages 112, 160, 161, and 375.

O. U. S. Patent No. 781,001 to Hewitt, granted January 31, 1905.

P. U. S. Patent No. 781,002 to Hewitt, granted January 31, 1905.

Q. Electricity and Magnetism, by James Clark Maxwell, published at Oxford, in 1892, vol. 1, page 310 to 313, inclusive.

R. Proceedings of the Institute of Radio Engineers, published at New York, 1920, vol. 8, pages 64 to 74, inclusive. (Article by Miller.)

S. The Principles Underlying Radio Communication published at Washington, 1919, pages 288, 304, and 313.

T. The Principles Underlying Radio Communication, published at Washington, 1922, page 402.

U. Electric Wave Telegraphy and Telephony, by J. A. Fleming, published at London, 1916, pages 98 and 109.

[fol. 567] V. Wireless Telegraphy and Telephony, by Eccles, published at London, 1918, pages 215, 216, and 220.

W. The Radio Review, published at London, England, October 1919, pages 26 to 29 incl. (Article by Eccles.)

X. Journal of the Institution of Electrical Engineers, London, 1900, vol. 30, page 232.

Y. Philosophical Magazine, published at London, England 1916, vol. 32, pages 426 and 427.

Z. Certified copy from the records of the Navy Department of the report by George H. Clark, on the Belli-Tosi Direction Finder Tests, dated Oct. 5, 1915.

A-1. Manual of Wireless Telegraphy for the use of Naval Electricians, published at Washington, 1915, pages 132, 133, 134, and 139 to 144, inclusive.

B-1. Robinson's Manual of Radio Telegraphy and Telephony published at Annapolis 1918, page 156.

C-1. Wireless Telegraphy and Telephony by Turner, published at London, 1921, page 88.

D-1. Guide to the Study of the Ionic Valve, published at London, 1919, page 19.

E-1. Proceedings of Physical Society of London, published at London, February 1914, page 102 (article by Coursey).

F–1. Bulletin of the Bureau of Standards, vol. 6, No. 4, published at Washington, 1911, pages 527 to 542, inclusive (article by Austin), on the "Comparative sensitiveness of some common detectors of electrical oscillations."

G–1. Practical Wireless Telegraphy, by Bucher, published at New York in 1918. Pages 143, 144, 145, 148, 151, 154, 157, 172, and 174.

H–1. Proceedings of the Institute of Radio Engineers for August, 1916, published at New York, August, 1916 (article by Shoemaker), pages 322 and 325.

I–1. Proceedings of the Royal Society, published at London, 1890, vol. 47, pages 118 to 126, inclusive.

J–1. Proceedings of the Royal Institute, London, 1890–1892, pages 34 to 49.

K–1. The Electrician, published in London, England, February 21, 1890, pages 393 to 395 inclusive.

L–1. The Electrician, published at London, England, February 20, 1890, pages 417 to 420, inclusive.

M–1. Proceedings of the American Institute of Electrical Engineers, published at New York, 1897, vol. 14, pages 31 to 35, 42 and 43, inclusive.

N–1. Proceedings of the Physical Society of London, published at London, England, March 27, 1896, pages 187 to 242, inclusive.

O–1. The Physikalische Zeitschrift, published at Berlin, Germany, October 20, 1904, pages 680 and 681.

P–1. Translation of defendant's Exhibit O–1.

Q–1. Annalen der Physik, published Berlin, Germany, April 20, 1904, pages 425 to 467, inclusive.

R–1. Translation of defendant's Exhibit Q–1.

S–1. Philosophical Magazine, published at London, England, 1898, vol. 46, page 528 (article by Thomson), beginning page 528.

[fol. 568] T–1. Philosophical Magazine, published at London, England, 1899, vol. 48, page 547 (article by Thomson), beginning page 547.

U–1. Philosophical Magazine, published at London, Englan, 1903, Vol. V (article by Thomson), beginning page 354.

V–1. Proceedings of the Cambridge Philosophical Society, published at London, England, 1901, vol. 11, page 286 (article by Richardson), beginning page 286.

W-1. Philosophical Transactions of the Royal Society, published at London, England, 1903, vol. 11 (article by Richardson), beginning page 497.

X-1. Proceedings of Cambridge Philosophical Society, published at London, England, 1897, vol. 9 (article by Townsend), beginning page 244.

Y-1. Proceedings of Cambridge Philosophical Society, published at London, England, 1897, Vol. IX (article by Wilson), beginning page 333.

Z-1. Proceedings of Cambridge Philosophical Society, published at London, England, 1903, Vol. V (article by Wilson), beginning page 429.

A-2. French Patent No. 328,687, granted May 7, 1903, to Valbreuse.

B-2. Translation of defendant's Exhibit A-2.

C-2. The Thermionic Valve, by J. A. Fleming, published at London, England, 1919, pages 102 to 116, inclusive.

D-2. Ground Telegraphy or T. P. S., Radio Pamphlet No. 10, published at Washington, 1918.

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Cross-examination of Dr. J. M. Miller:

34. Cross-question. Doctor Miller, please state what practical experience you have had in connection with the radio art, particularly in connection with vacuum tubes?

Answer. I have seen and operated practically all common types of radio apparatus employing vacuum tubes. In the laboratory I have investigated the operation of the tubes themselves and of the apparatus in which the tubes are used.

35. Cross-question. Your work has been substantially entirely experimental work, has it not?

Answer. It has been largely experimental, but in many cases the experiments duplicated commercial transmitting and receiving work.

36. Cross-question. The work was largely conducted in laboratories, was it not?

Answer. It was largely conducted in a laboratory, though some of my work has been on board the ships of the United States Navy; also in radio compass stations of the United States Navy.

37. Cross-question. Please define the word "detector" in the sense that you have been using it in your direct examination.

Answer. My definition of the term "detector" as I have used it in my direct examination coincides very closely with the definition given by Eccles and quoted in my answer [fol. 569] to question 8. "Detector—a receiving instrument for converting high-frequency current or voltage into a form of current or voltage capable of affecting an indicating instrument such as a galvometer or telephone receiver."

38. Cross-question. That is, you have used the word in the restricted sense as referring to that particular device which modifies the radio-frequency currents in such a manner as to make them detectable to the human senses?

Answer. I do not know that I have used the term in the restricted manner, but believe that I have used it in accordance with the art.

39. Cross-question. Have you used it in the sense defined in cross-question 38?

Answer. No; I do not think I have. It is not necessary that the output of a detector should be detectable to the human sense. The operation of the detector is such as to convert to a type of current which may be detectable by the human sense if of sufficient intensity.

40. Cross-question. Please state what experience you have had with detectors other than those of the vacuum-tube type.

Answer. My experience with other types of detectors has been largely confined to the crystal detectors.

41. Cross-question. Is the term "detector" synonymous with the term "rectifier"?

Answer. I would not consider them to be synonymous.

42. Cross-question. Please give some examples of detectors that are not rectifiers.

Answer. I do not believe that I would classify the original coherer as a rectifier; likewise the so-called Zehnder trigger tube.

43. Cross-question. How about the Marconi magnetic detector and the so-called dynamic telephone?

Answer. I would not classify these as rectifiers.

44. Cross-question. Please state what experience you have had with vacuum tubes containing only two electrodes.

Answer. The vacuum tube containing only two electrodes is not very common in the art, and I have not had a great deal of experience with such tubes. I have investigated and made tests on high vacuum two-electrode vacuum tubes

known as "kenotrons". I have investigated the functioning of these tubes to some extent in the laboratory.

45. Cross-question. Were these "kenotrons" designed or sold for radio work?

Answer. They were not sold for radio reception. They were used in connection with radio equipment, but not as detectors for radio reception.

46. Cross-question. What was the purpose for which they were sold?

Answer. They were utilized to regulate the voltage of generators used in aircraft-radio transmission.

47. Cross-question. They were used in low-frequency circuits then, were they not?

Answer. I would say they were used in connection with direct current.

48. Cross-question. Please state what physical portion of a complete vacuum-tube receiving set you refer to as the detector.

Answer. I refer to the portion of the receiving set which brings about the frequency conversion referred to in my definition under Cross-question 37. In my direct examina- [fol. 570] tion I have pointed out, however, that the term "detector" is loosely applied to a three-electrode vacuum tube, which is simultaneously performing both the functions of detection and amplification.

49. Cross-question. Does not a three-electrode vacuum tube performing those functions come within your definition of the work "detector"?

Answer. It does, in my definition of a detector, but includes more.

50. Cross-question. Referring to Miller drawing H, please state what portion of the apparatus and circuit shown therein is the detector.

Answer. In vacuum tube No. 4 there is taking place both detection and amplification; commonly tube 4 and its circuits would be called the detector. It is very difficult to separate and clearly distinguish those parts which enter into the detecting action and those which enter into the amplifying action. The grid condensed C'' and grid leak r indicate to me that this tube is intended to operate as a detector in this amplifying unit.

51. Cross-question. Does not a certain amount of detecting action also occur in vacuum tubes Nos. 1, 2, and 3?

Answer. There may or may not be a certain amount of detecting action taking place in tubes 1, 2, and 3; such action, however, if present would have no effect on the operation of the amplifier.

52. Cross-question. Comparing two-electrode and three-electrode vacuum tubes, both of them are inclosed in a glass vessel, are they not?

Answer. They are.

53. Cross-question. And this vessel is highly evacuated?

Answer. Yes, to varying degrees.

54. Cross-question. Each contains at least two conducting members or electrodes sealed within the vessel and both physically and electrically separated, does it not?

Answer. Yes.

55. Cross-question. One of these electrodes is designed to act as a cathode or source of electrons, is it not?

Answer. Yes.

56. Cross-question. This effect is obtained in substantially all present-day types of vacuum tubes by heating the cathode to incandescence?

Answer. Yes.

57. Cross-question. A source of energy for heating the cathode to incandescence must necessarily be used with both two-electrode and three-electrode vacuum tubes in order to make them operate?

58. Cross-question. Is it also necessary that a circuit outside of the vessel connecting the two electrodes must be used?

Answer. In the case of the two-electrode tubes there is such a circuit; in the case of the three-electrode tube there are in general two circuits.

59. Cross-question. Each of those two circuits is connected to the cathode, is it not?

Answer. Yes.

60. Cross-question. Is it true that in both two-electrode and three electrode vacuum tubes there is a nonheated electrode (commonly called an anode), which is used as a [fol. 571] collector of the electric charges carried by the electrons emitted from the cathode or a portion of them?

Answer. Yes; such an anode is present in the two-electrode tubes of Edison and Fleming and also in the three-electrode tube of DeForest.

61. Cross-question. When the two-electrode and three-electrode tubes are being used, is there not associated with

each of them some means for impressing upon the cathode and another electrode within the vessel the variations in potential caused by the received oscillations?

Answer. There is a means of applying the variations in potential caused by the received oscillations. These variations are applied in general between the plate and filament in the case of the two-electrode tube and between the grid and filament of the three-electrode tube.

62. Cross-question. Is it also true that in each case there is an indicator either in or electrically associated with the anode-cathode circuit for the purpose of making the reception of oscillations detectable to the human senses?

Answer. There may or may not be such an indicator?

63. Cross-question. Please explain how these devices could be commercially useful without such an indicator?

Answer. My drawing H, to which reference has just been made, shows the connections of a commercial receiving device. In this device tube 4 performs the conversion from radio to audio frequencies. The telephone receiver, which is the indicator, is, however, not located in the circuit of tube 4 at all but is included in the circuit of tube 6.

64. Cross-question. Would you not say that the telephones were electrically associated with the anode circuit of tube 4?

Answer. No; I would not.

65. Cross-question. Do they not indicate the variations in current flowing in the anode circuit of tube 4?

Answer. The indications are perhaps proportional to the variations in the current flowing in the anode circuit of tube 4 but are many times multiplied.

66. Cross-question. Do they not indicate the existence of variations in the current flowing in that circuit?

Answer. Yes; if the multiplication is sufficient.

67. Cross-question. In order to be of commercial value, is it not necessary that the telephones indicate the existence of such variations?

Answer. Yes.

68. Cross-question. Is it true that in the case of both two-electrode and three-electrode vacuum tubes there is an indicator for the purpose of indicating the existence of variations in the current flowing in the anode-cathode circuit?

Answer. Yes.

69. Cross-question. Is it not true that the elements and characteristics of three-electrode vacuum tubes and their associated circuits, which you have stated exist in your answers to cross-questions 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, and 68, are necessarily present in all commercial installations?

Answer. No. The indicator, for example, is not necessarily present and is in general not present in many commercial installations of three-electrode vacuum tubes.

[fol. 572] 70. Cross-question. Is it not necessary that there be some indicator to indicate the existence of current variation in the anode circuit?

Answer. In the use of the three-electrode vacuum tube for radio reception an indicator is used somewhere in the receiving system. In the use of the three-electrode vacuum tube for transmission purposes no such indicator is required.

71. Cross-question. Even when the three-electrode vacuum tube is used for transmission purposes, such an indicator is always present in the receiving end of the system, is it not?

Answer. There would be an indicator at the receiving end of the system which might be thousands of miles from the three-electrode vacuum tubes, which are effecting the transmission.

72. Cross-question. Even then the indicator would indicate the variations in the anode current of the transmitting tube, would it not?

Answer. No; it would not in general.

73. Cross-question. It would, however, indicate the existence of such variations, would it not?

Answer. It would doubtless indicate the existence of variation in the transmitter tube, but the variations affecting the indicator could be entirely different from the variations taking place in the transmitting tube.

74. Cross-question. Leaving out of consideration the indicator, how would you answer cross-question 69?

Answer. I will also have to qualify my answer with respect to the matter of impressing received oscillations. In the case of three-electrode vacuum tubes when used as transmitters, there is no means for impressing received oscillations upon the tube. Otherwise, I believe that the elements and characteristics stated in my answers to the

questions indicated are necessarily present in a commercial installation.

75. Cross-question. Even in the case of transmitters, is it not true that some oscillations are impressed upon the tube?

Answer. Yes.

76. Cross-question. Comparing the mode of operation of two-electrode and three-electrode vacuum tubes, is it true that both devices operated by virtue of variations in the flow of the electrons from cathode to anode?

Answer. Yes.

77. Cross-question. Is it true that the anode current to which we were referring this morning varies simultaneously with and in phase with the variations in electron flow?

Answer. Yes; they are practically identical currents.

78. Cross-question. And is it true that the variations in electron flow are caused by variations in the potential impressed upon the electron stream or a part of it from a circuit outside of the vacuum tube?

Answer. No. In the case of the two-electrode tube it may be said that the variations in electron flow are caused by variations in the potential impressed upon the electron stream, but in the case of the three-electrode tube the variations are not produced by a potential impressed upon the electron stream, or a part of it.

[fol. 573] 79. Cross-question. What causes the variations in the electron flow in the three-electrode vacuum tube?

Answer. The variations in flow in the three-electrode tube are caused by potentials which are impressed upon the grid of the tube. In general, the electron flow does not take place between the cathode and the grid member and hence the potential variations are not impressed upon the electron flow. The action of the grid is such however, as to influence the flow taking place between the cathode and anode of the three-electrode tube. This point is of considerable importance in distinguishing between the operation of the two devices. The action of impressing the potential variations upon the current flow is one which requires power. The control exerted by the grid of the three-electrode vacuum tube is one which requires little or no power.

80. Cross-question. Is it true that in both the two-electrode and three-electrode vacuum tubes the flow taking

place between the cathode and anode is influenced by variations in potential which are caused by the received oscillations?

Answer. Yes; in the case of two-electrode tube this is direct; in the case of the three-electrode tube it is indirect, or through the action of the grid.

81. Cross-question. In the case of the two-electrode tube, is it true that the electron flow from cathode to anode increases when a positive potential is impressed upon the stream?

Answer. Yes; and the impressed positive potential directly produces the increased current flow.

82. Cross-question. And in the case of the three-electrode vacuum tube, is it true that the electron flow from cathode to anode is increased when the grid is positively charged?

Answer. Yes; but in this case the positive charge on the grid does not directly produce the increased current flow. It is merely the controlling effect of this charge upon the current flow between the anode and cathode that permits a greater current flow between these two electrodes. A positive potential upon the grid does not supply the increased flow of current.

83. Cross-question. Am I correct in understanding that the chief difference between the influence or control of the grid in the three-electrode tube and of the anode in the two-electrode tube is that one is indirect and the other direct?

Answer. No. In the first place, I do not like the use of the term "control" in connection with the voltage applied to the anode of the two-electrode tube. This term is usually reserved for the action of the grid of the three-electrode tube. The main difference is that of a device which is an amplifier and another device which is not an amplifier. The voltages applied to the grid of the three-electrode tube do not themselves produce the current flow or changes in current flow, and hence little or no power is expended in varying the potential of the grid. The variations in grid potential, however, control the current between the anode and cathode. These latter current variations represent considerable power. Hence the variations of considerable power are produced by original voltage variations which are required to supply little or no power. This is an amplifying device. In the case of the two-electrode [fol. 574] tube, when variations in voltage are impressed between the cathode and anode, the changes in current flow

are directly produced by the applied voltage variations and the applied voltage must supply the power represented by these currents. This is not an amplifier and the variations in current would not be called control variations.

84. Cross-question. Is it true that the instantaneous potential of the anode in the two-electode tube determines the electron current at that instant?

Answer. Yes.

85. Cross-question. Is it true that the instantaneous potential of the grid in the three-eletrode tube determines the electron current at that instant relative to the normal electron current caused by the anode battery?

Answer. Both the instantaneous potential of the grid and of the anode determine the electron current in the anode circuit at any instant in the case of the three-electrode vacuum tube.

86. Cross-question. In general, to what extent and in what way, if at all, is the anode potential influenced by the receiving oscillations?

Answer. In the case of the three-electrode vacuum tube, when being used as a radio-frequency amplifier, the variations in plate or anode potential are directly opposite to the variations of potential upon the grid. Thus, when the grid is becoming more positive, the anode is becoming less positive. In the case of the three-electrode vacuum tube when being used as a detector, the voltage variations of the grid are of two kinds, viz, radio-frequency and audio-frequency. In general, in this use of the vacuum tube the variations of anode potential would be audio-frequency variations alone and oppositely directed to the audio-frequency variations upon the grid. The variations in the anode potential depend upon the electrical apparatus included in the anode circuit of the vacuum tube, or rather upon the impedance of such electrical apparatus.

87. Cross-question. Are your answers to cross-questions 76, 77, 81, 82, 84, and 85 correct, regardless of the purpose for which the vacuum tubes are being used?

Answer. My answers to these questions are correct for any ordinary and usual purposes for which vacuum tubes are used.

88. Cross-question. Including detecting, amplifying, and generating oscillations?

Answer. Yes; in so far as they go.

89. Cross-question. Is your answer to cross-question 80 correct as applied to both detecting and amplifying?

Answer. Yes; excepting that in the actual uses of the tubes we are not restricted to variations in potential which are caused by received oscillations.

90. Cross-question. With the same exception, your answer would be correct as applied to the use of vacuum tubes for generating oscillations, would it not?

Answer. I find that my previous answer implies that the two-electrode vacuum tube can be used as an amplifier. This is not true. In answering the present question, I would be admitting by implication that the two-electrode vacuum tube is capable of operating as as oscillator. This is also not true. In so far as the flow between the cathode [fol. 575] and anode is influenced by variations in potential, my answer to cross-question 80 is correct.

91. Cross-question. And is correct as applying to three-electrode vacuum tubes whether detecting, amplifying, or oscillating?

Answer. Yes; that is, the flow taking place between the cathode and anode in the three-electrode vacuum tube is influenced by variations in potential of the grid.

92. Cross-question. What are the physical differences that exist between all two-electrode vacuum tubes and all three-electrode vacuum tubes?

Answer. The main distinguishing feature between the two-electrode vacuum tubes, such as the Edison or Fleming devices, and the three-electrode vacuum tubes, such as the De Forest audion, is the inclusion in the latter of a control electrode or element. There are numerous other variations from tube to tube with respect to size, arrangement of the electrodes, degree of vacuum, etc.

93. Cross-question. Outside of the inclusion of the third electrode and the necessary terminal therefor, is there any other difference which is always present?

Answer. I can think of no other important difference in the tubes themselves.

94. Cross-question. So far as you know, was there anyone prior to John Ambrose Fleming who disclosed the use of a two-electrode vacuum tube in connection with radio signaling?

Answer. Limiting my answer to the type of two-electrode vacuum tube with the heated filament and additional anode

member, I know of no one prior to John Ambrose Fleming who disclosed its use in connection with radio signaling. The use of this type of two-electrode vacuum tube as a rectifier for low-frequency currents was, however, disclosed prior to the date of the Fleming patent.

95. Cross-question. How does the degree of vacuum employed in mercury vapor lamps compare with that employed in vacuum tubes of the type referred to in your last answer?

Answer. I would estimate that the vacuum employed in mercury vapor lamps is equal or of a somewhat lower degree than the lowest degree of vacuum which has ordinarily been employed in two-electrode vacuum tubes.

96. Cross-question. Do mercury vapor lamps operate by virtue of the electron flow?

Answer. Yes.

97. Cross-question. How important a part does ionization take in the operation of mercury vapor lamps?

Answer. Ionization in mercury vapor lamps is of considerable importance in determining the current flow in such lamps.

98. Cross-question. Are such lamps used commercially in connection with radio signaling?

Answer. Not to my knowledge.

99. Cross-question. Have you experimented with the production of high-frequency oscillations by a two-element vacuum tube?

Answer. Yes.

100. Cross-question. What proportion of the tubes with which you experimented were you able to cause to produce such oscillations?

Answer. With high-vacuum two-electrode vacuum tubes I was unable to obtain oscillations with any tubes, even [fol. 576] though I exhausted every effort in the attempt to obtain such oscillations. With low-vacuum three-electrode vacuum tubes, which were converted into two-electrode tubes by connecting the grid and plate electrodes together, I have been able to obtain more or less erratic and variable oscillations under abnormal operating conditions, with practically all of the tubes that I tested. These tubes were chosen by me because I believed that they contained sufficient gas to permit the generation of oscillations by an action similar to that of the arc.

101. Cross-question. Are the high-vacuum two-electrode vacuum tubes to which you referred in your last question the "kenotrons" to which you referred this morning?

Answer. Yes. These tubes had a tungsten filament surrounded by a cylindrical plate, and though not sold for use as radiodetectors could be used as such with perhaps as good results as any other high-vacuum two-electrode vacuum tube.

102. Cross-question. Did you actually use them as detectors?

Answer. I do not remember that I have, but I know that they could be so used.

103. Cross-question. Is it true as a general principle that any device which will generate oscillations will also amplify?

Answer. No; but I believe the converse is true. In order to know whether or not an oscillation generator will be capable of amplifying, it is necessary to know something of the mechanism of the device, but in general a device which will amplify is capable of generating oscillations.

104. Cross-question. Is it true that any vacuum tube which will oscillate will also amplify?

Answer. Not necessarily. I would expect that a vacuum tube which generates oscillations in a manner similar to the arc could possibly be made to amplify.

105. Cross-question. Are all of the three-electrode vacuum tubes which were purchased by the United States, capable of use in commercial radio signaling?

Answer. To the best of my knowledge, they were all capable of use in radio signaling, though they were not all used in connection with radio signaling.

106. Cross-question. Were they used for any purpose other than radio signaling, except for the so-called T. P. S. system of ground telegraphy?

Answer. I know of no other major use of the tubes for purposes other than radio signaling, excepting the T. P. S. system of ground telegraphy.

107. Cross-question. For what purpose were they used in that system?

Answer. They were used as audio-frequency amplifiers. The currents used in T. P. S. signaling are entirely low or audio-frequency currents. The currents picked up at the receiving station are in general too feeble to be heard when telephone receivers are used directly. Amplifiers utilizing

the three-electrode vacuum tubes were employed to multiply the power of these audio-frequency currents so that they were capable of actuating the telephone receivers.

108. Cross-question. Did the vacuum tubes used in this system operate in any different manner from tubes 5 and 6 in Miller drawing H?

[fol. 577] Answer. I would say that the operation was entirely similar.

109. Cross-question. Then the T. P. S. receiving sets were equally adapted to be used as audio-frequency amplifiers in connection with radio receiving sets?

Answer. Yes; in both cases it is a matter of amplifying audio-frequency currents, and, as I pointed out in my answer to question 30, the amplifier had three binding posts, two which were used for T. P. S. signaling, and two of which were used in connection with radio signaling. It is a matter merely of fitting the amplifier to the circuit in which it is being used.

110. Cross-question. Is it not true that in many cases it is necessary to use an audio-frequency amplifier in connection with radio-receiving apparatus in order to make the received signal detectable to the human senses?

Answer. It is true that in many cases when a signal is inaudible in the telephone receiver it can be made audible by including an audio-frequency amplifier in the circuit. I have just pointed this out in connection with the T. P. S. method of ground signaling, and it is likewise true in the case of radio signaling. One must, however, not confuse the technical meaning of the term "detection" with the ordinary meaning of the verb "to detect." In the T. P. S. method of signaling, detection and detectors are not employed, though the use of the audio-frequency amplifier makes it possible to detect a signal that would likewise be inaudible.

111. Cross-question. Using the "ordinary meaning" of the word "to detect," is not an audio-frequency amplifier necessarily employed to detect the signal when without such amplifier the signal would be too weak to be audible?

Answer. Yes; but technically one would not speak of using an audio-frequency amplifier to detect a signal. The meaning of detection is technically limited to the process of frequency conversion from the high radio-frequency, which

is transmitted, to the low or audible frequency, which is capable of actuating a telephone receiver.

112. Cross-question. The conditions referred to in the preceding question are not uncommon, are they, in practice?

Answer. I would say they are not uncommon.

(The examination by counsel being concluded, the witness, in compliance with the rule of the court requiring him to state whether he knows of any other matter relative to the claim in question, and if he does to state it, says he does not.)

(Deposition closed.)

Deposition of Robert A. Millikan, for defendants, taken at New York City on the 27th day of December, A. D. 1923

Robert A. Millikan, having been produced as a witness on behalf of the defendant, was by me sworn before any question was put to him, to tell the truth, the whole truth, and nothing but the truth relative to the said question, and [fol. 578] thereupon deposed and said that his name was Robert A. Millikan; that his occupation is physicist, California Institute of Technology, director of the Norman Bridge Laboratory of Physics, Pasadena, Calif.; that he is 55 years of age; that his residence is Pasadena, Calif.; that he has no interest, direct or indirect, in the claim in controversy; and that he is not related to plaintiff; and thereupon the said Robert A. Millikan was examined by counsel for the defendant and in answer to interrogatories testified as follows:

Direct examination.

By Mr. Edwards:

1. Question. What has been your training and experience in scientific and electrical matters, particularly your experience with electrical discharges through evacuated space or gases?

Answer. I took the doctor's degree in physics from Columbia University in 1895. For one year and one-half thereafter I was a student in Berlin and Goettingen, and then came to the University of Chicago, where I remained

from the fall of 1896 up to 1921, when I accepted the directorship of the Norman Bridge Laboratory of Physics of the California Institute of Technology at Pasadena.

My undergraduate course was taken at Oberlin College, Ohio. I have received honorary degrees for my scientific work from four or five universities, the doctor of science from Columbia University, from University of Pennsylvania, from Northwestern University, from Oberlin College, and from Amherst College.

My experience in the field of discharge of electricity through gases, perhaps, may be said to begin in 1896, when I was working in the laboratory in Goettingen with a man by the name of Potter, who was then with the Westinghouse Co., who was working on the negative resistance of the arc. We used to call it in those days the electromotive force of the arc, and I followed the literature and the development in that field, which were rapid during the next four or five years.

After becoming associated with the University of Chicago I spent a good fraction of my time from, say, 1903 up to the present on the study of the general subject of electronics, much of my experimental work having to do with the discharge through gases.

As a result of that work, I have published a large number of papers in the technical journals on discharge through gases, perhaps the most well-known contributions being the "Isolation of the ultimate electrical unit" and the actual counting of the number of electrons in small charges. This work furnished a complete demonstration of the atomic character of electricity.

The publication of it began in 1909, but there has been a whole series of publications, extending up to last year. The complete summary of all that work is contained in a book which appeared in 1917 which is entitled "The Electron, Its Isolation and the Determination of Some of Its Properties."

For some of this work I was awarded the Comstock prize of the National Academy of Sciences in 1912 or 1913.

I am past president of the American Physical Society and vice president of the American Association of the Advancement of Science, and am at present vice chairman of the National Research Council.

[fol. 579] During the war I held the commission of lieutenant colonel in the Army and the position of chief of the

science and research division of the Signal Corps, which in the spring of 1918 became the science and research division of the Department of Military Aeronautics. I have been the recipient of the Edison medal of the American Institute of Electrical Engineers, of the Hughes medal of the Royal Society of Great Britain, and of the Nobel prize, all for work in the electrical field, especially in the investigation of electronic phenomena.

In all this work I have had considerable familiarity with electron tube work, having been fairly closely associated with the development of tube amplifiers from the very inception of that development by the telephone company in 1912.

2. Question. Are you familiar with the three electrode electron tube devices of the type purchased by the Signal Corps during the war?

Answer. I am quite familiar with those devices, both because of my connection with the Signal Corps and with the Bureau of Steam Engineering of the Navy as a civilian of the antisubmarine board.

3. Question. Are these devices high-vacuum devices?

Answer. They are.

4. Question. How high is the vacuum?

Answer. Measurements which I have made on their commercial audion type bulbs have shown a pressure of, the order of 10^{-5} millimeters; that is, one one-hundred thousandth of a millimeter.

My own work in my own laboratory with tubes of this sort, evacuated by exactly the same methods which are used by the Western Electric Co. in their manufacture of these tubes, has shown these pressures to vary from 10^{-7} up to 10^{-5}, and sometimes higher, but that would be the order of magnitude of the pressure existing in those tubes, according to such measurements as I have myself made.

5. Question. Atmospheric pressure is about 760 millimeters of mercury, is it not?

Answer. It is under standard conditions.

6. Question. And this pressure in defendant's tubes of the range or nature of one one-hundredth thousandth of a millimeter is a pressure that would raise a column of mercury one one-hundredth thousandth of a millimeter; is that it?

Answer. That is what it means; yes.

7. Question. Does gas or vapor take any part in the operation of these devices?

Answer: It plays no appreciable role, as can be seen from the fact that the current between the filament and the negative grid is wholly negligible in comparison with the current which flows between the filament and the plate. If there were any appreciable amount of gas present, it would be ionized by the bombardment due to the negative electrons emitted by the filament, and the positive ions thus formed would produce a current to the negative grid, for the potential between the filament and the plate is normally above the ioninzing potential of any gas.

8. Question. Is what is called the electronic current a current the flow of which is not in any way associated with the presence of a gas or vapor?

Answer. It is completely independent of the presence of gas or vapor.

[fol. 580] 9. Question. Ionization related merely to an action upon the molecules of a gas or vapor, does it not?

Answer. Yes; ionization is the splitting up of molecules into positively and negatively charged parts. In gas tubes this is accomplished by electronic bombardment, and also under certain circumstances by the bombardment of positive ions.

10. Question. Why, if you know, does the Signal Corps and telephone company use the pressure that it does use in its tubes instead of having no pressure there at all?

Answer. It is not possible to have no pressure there at all in the strict sense of the word pressure, and it is uneconomical to produce a lower pressure than is sufficient for the satisfactory operation of the device. The manufacturers of tubes use as good a vacuum as they can obtain with a reasonable expenditure of money and time in producing them.

11. Question. Does the device work any differently if there is less pressure than that commonly used?

Answer. No; not at all. The pressure is reduced sufficiently so that the residual gases play no part in the phenomena going on in the tube.

12. Question. Will you explain the essential difference or differences in operation between the three electrode tubes of the type that you have been discussing and the two electrode types of electron tube such as shown, for example, in the Fleming patent No. 803684, a copy of which I show

you, assuming both types of tubes to be high-vacuum tubes and assuming both tubes to be used in wireless or wired telegraphy or telephony. By high-vacuum tube I refer to the so-called hard-vacuum tube.

Answer. For the purposes of communications, the two-electrode tube, which you refer to, is an electric valve or rectifier, pure and simple. It can detect and render signals either visible or audible solely by virtue of that rectifying action. When by virtue of the reception of high frequency waves the filament is negative with respect to the plate, a pure electron current passes from the filament to the plate and into the external circuit which joins these two electrodes and is capable of influencing a galv-ometer or telephone in that circuit.

When the impressed waves render the filament positive with respect to the plate, they can drive no current through the afore-mentioned circuit, since there are no positive carriers to pass between the electrodes in the tube. Hence, the galvanometer or telephones cases to register a current. With the high-frequency waves used in wireless, the alternations between the passages of current and the stoppages of current take place so rapidly that the inertia of a galvanometer suspension or of the telephone diaphragm prevents either of them from registering these changes. The registering instrument, in general, therefore, gives its indication during all the period during which the waves are falling upon it, and returns to its normal position when they cease to fall upon it. In this way, it renders visible or audible the presence or absence of waves whose frequency is enormously higher than could be normally detected by a galvanometer or a telephone. Thus, the rectifying or valve property of such a tube renders it useful as a detector of high frequency waves. A two-electrode tube of this kind with its electrodes connected by a circuit containing [fol. 581] a galvanometer, telephone, or other similar registering device does not and can not act as an amplifier. It met with useful application in the communications art only for the reception or detection of signals. About the fall of 1911 the telephone company set themselves the task of developing a telephone relay or amplifier, and after long experimenting developed the three-electrode tube in precisely the form used by the Government during the war as a most successful speech amplifier or telephone relay. The essential difference between the three electrode and the two

electrode tubes, for the communications art, is then that the well-exhausted two-electrode tube is simply a rectifier, and by virtue of that property can be used as detector of signals, but it is not and can not be an amplifier, whereas the three electrode tube was developed primarily for telephone amplification for the very reason that the two-electrode tube could not be so used, and the primary use of the three-electrode tube throughout the war was for the purpose of amplification and is that to-day. The essential function of the well-known telegraphic relay or amplifier in use all over the world since about 1840 is illustrated in Figure 1 of the drawing which I here insert.

Electrical energy coming in from the line to the left is passed through a transformer and by acting upon an electromagnet 2 closes through the motion of an armature 3 a second independent circuit which is supplied with a new source of energy, the battery 6. The energy value of the signal in the new circuit 5 now depends wholly upon the electrical constants of this second circuit and may therefore be as many times as is desired the energy value of the signal coming in through the line from the left. The new signal which is thus passed on to the line 8 to the right bears no necessary quantitative relation so far as its energy is concerned to that which came in to the line from the left. This same Figure 1 may be used to illustrate the essential elements of a mechanical telephone repeater or amplifier if 4 is now thought of as a carbon button or microphone, the pressure between which and the armature 3 is controlled by the currents passing through the electromagnet 2. Such a telephone relay or amplifier has actually been used in practice on telephone lines, but not very successfully, because of the impossibility of the current in 5 following accurately the relative changes of the incoming current in 1. The electron tube telephone amplifier was developed for the sake of replacing an inertialess electron stream, the inertia-laden moving part 3 of a mechanical repeater. The circuits of the electron telephone relay or amplifier are shown in Figure 2 and are essentially the same as those shown in Figure 1. The incoming electromotive forces from the line 2 are passed through the transformer to the left so as to operate between the filament and the grid of the electron tube. These changes in the electrical field surrounding the grid act upon the new circuit 12 so as to control the currents flowing in that circuit

from the battery 6 and therefore flowing between the filament and the plate in essentially the same way as the pressure between the armature and the carbon button 3 and 4 in Figure 1 control the currents delivered to circuit 5 by the battery 6 of that figure. The essential difference is merely that the distortion-full amplification by the mechanical relay of the wave form coming to it through the electromagnet 2 is replaced by a distortionless amplification by the inertialess electronic relay of Figure 2. The ampli-[fol. 582] fication factor in the device illustrated in Figure 2 may be chosen at will precisely as in the case of the mechanical relay shown in Figure 1. In actual practice it often amounts to five hundred or a thousand fold. The essential difference, then, in a word, between the two-electrode tube and the three-electrode tube, so far as the communications art is concerned, is that they were developed for entirely different purposes and actually fulfil completely different functions, the first being simply a rectifier and detector and incapable of performing either in a scientific or commercial way the function of amplification, while the second was developed for and now serves magnificently the purposes of distortless amplification.

13. Question. What is meant by amplification?

Answer. I should define it as the passing on from one circuit to another of a signal or of speech with increased energy, because of the utilization for the purposes of the signal of the energy of a new battery or other source of some kind.

(Counsel for defendant offers in evidence the sketch referred to by Doctor Millikan in his answer to question 12, and the same is marked "Defendant's Exhibit E2.")

14. Question. Can you state in a general way what commercial importance the amplification function has?

Answer. I suppose that the outstanding commercial application of amplification is in the field of wire telephony, transcontinental telephony, having been possible solely through the development of a distortionless telephone repeater or amplifier, and I suppose too that the great bulk of its use in the wireless field, small though that field be in comparison with the former, is in the distortionless amplification of speech, for every broadcasting, receiving, or transmitting set of the better type involves just this use.

15. Question. Is the distortionless repeater or amplifier

above referred to as in extended use the three-electrode tube or the two-electrode tube?

Answer. It is precisely the three-electrode tube whose functioning I have been above describing.

16. Question. In your opinion, would this extended use of electron tubes in the telephone and wireless field have been possible with the two-electrode type of tube only?

Answer. Certainly not.

17. Question. In your comparison of the two-electrode type of tube with the three-electrode type of tube, would this comparison be changed, or would the operation of the tubes be changed, whether the tube is operated at radio-frequency or audio-frequency?

Answer. The amplifying qualities of a three-electrode tube, or triode, are quite the same for radio frequencies as for audio frequencies.

18. Question. If a battery be inserted in the circuit of a two-electrode tube, still assuming a high, that is to say, hard, vacuum tube, for example, as shown in the circuit marked "Figure 3" of Miller drawing L (defendant's Exhibit I), would the tube act as an amplifier?

[fol. 583] Answer. The device shown in this diagram is equally incapable, with that which I have been discussing, of amplication in any degree whatever. The local battery in the circuit of Figure 3 is indeed continually supplying direct-current energy to that circuit, but this adds nothing to the alternating-current energy of the signal coming into the circuit with which it is coupled. In other words, for the purposes of the signal, the energy of the inserted battery is not tapped in the slightest degree. Indeed the energy available for and spent in signalling, is slightly diminished because of the ohmic resistance of the inserted battery. It is true that signals may sometimes be heard better when a local battery is inserted, as in Figure 3, than when it is absent, especially when the detector which is in series with the battery is a crystal; but this is merely due to the fact that the resistance of the crystal, or the crystal and its contact point, when it is carrying a current of some magnitude is often less than its resistance when it is carrying a very small current or no current at all. This merely means that the resistance of the whole circuit with the battery inserted may be less than its resistance with the battery absent, and therefore, at the same dissipa-

tion of energy by the signal, may give rise to a larger current, through the detector. While the battery may thus act as a sensitizer of the circuit for the signal, its own energy is not utilized at all in the alternating current of which the signal consists. A hard tube with or without a battery is equally incapable of amplification.

19. Question. In the circuit referred to, would there be any difference so far as obtaining amplification is concerned, if a crystal detector were inserted in place of the two-electrode hard vacuum tube?

Answer. In general, no. No device in a series circuit of this kind can possibly produce amplification, if it has a positive volt-ampere characteristic, that is, if an increasing potential difference applied to its terminals produces a continually increasing current passing through it. Every hard two-electrode tube has such a potential current characteristic, and must have because of its very nature. Crystal detectors also in general have such so-called positive characteristics. I think it possible however, that a freak crystal might be found which would have a negative volt-ampere characteristic, because of the existence of something like an arc at its contact point, and if this were so it would theoretically, at least, have the capacity of a certain kind of amplification, which I will designate as the negative resistance type of amplication, in order to differentiate it sharply from the relay type of amplification exhibited by any telegraph or telephone relay such, for example, as a triode tube. This relay type of amplification is that which is produced in the three electrode tube circuit described in the foregoing.

In general, triode tubes, like diode tubes, if they are well exhausted, have necessarily positive volt-ampere characteristics, that characteristic being taken between the filament and the plate.

[fol. 584] 20. Question. What would be the result of introducing or leaving in the two-electrode bulb a small amount of gas, so far as relates to the possibility of attaining amplification?

Answer. There would be no effect at all, unless the gas exceeds a certain critical amount. If, however, enough gas is present to permit the formation of an arc between the filament and the plate, or of a conducting region, which has the charactertistics of an arc, it would be possible to

obtain with the two-electrode tube a certain imperfect type of amplification which I have designated in the foregoing as the negative resistance type of amplification, in order to differentiate it sharply from the relay type, for which the three-electrode tube is so well adapted. Any space between two electrodes in which it is possible to obtain a large amount of ionization of gases or vapors may under suitable conditions exhibit the peculiar property of having what is often termed a negative resistance. A negative resistance is defined as a negative value of the increment in potential causing current to flow between two points over the increment in current. If we insert such a space, which for brevity I will henceforth term an arc, in series with a circuit otherwise containing a battery and a resistance, if the arc has this negative characteristic for the impressed frequency, then the effect of the negative resistance of the arc upon the current flowing through the circuit is equivalent to the substraction of a certain amount of the resistance that is already in the circuit, so that the current which flows through it is larger than could be obtained if the arc were not there. In this case the alternating energy of the signal may be actually increased at the expense of the battery inserted in the receiving circuit. The principle here involved is the introduction into a series circuit of a negative resistance which produces amplification simply because it annuls a certain part of the resistance which the circuit already had. In this case there will be amplification in just the proportion which the substracted resistance bears to the resistance of the whole circuit. If, for example, the inserted device has a negative resistance of 1 ohm and the circuit a resistance of 500 ohms, then the alternating signal will be one five-hundredth stronger than it was before. If, on the other hand, the positive resistance of the circuit into which a negative resistance of 1 ohm is inserted, was 10 ohms, then the signaling current will have been increased or amplified 10 per cent or by a factor of one-tenth. I have measured the negative resistances of arcs, both in partially exhausted tubes and out of them, and have usually found them of the order of 1 or 2 ohms. I do not think I have ever measured one that had a negative resistance of as much as 10 ohms. This shows one of the limitations of this type of amplification. It has practically no effect at all when used in circuits of resistances larger

than a few ohms. A second more important limitation lies in the fact that these negative resistances in general represent rather unstable conditions, and hence are subject to very considerable variations so that it is practically impossible to cause one of them to have any specified amplication coeffi- [fol. 585] cient or ratio at all such as is necessary if they are used for the purposes of commercial amplification. Negative resistances have as a matter of fact never had the slightest value. This type of amplification is therefore sharply differentiable both as to method and results; indeed, I should say as to principle also, from the relay type of amplification used for years in telegraphy and now introduced into telephony through the development of the three-electrode amplifier, which makes it possible to obtain any desired amplification ratio or amplification coefficient. I may say also that the whole subject of negative resistances was one about which there was much discussion and no little confusion in thinking between 1890 and 1900. It was very beautifully cleared up by some papers which appeared in the London Electrician by Duddell in 1900 (vol. 46). Since that time there has been I think general agreement among competent students of the subject upon the essential points which I have been discussing in the preceding. The whole field is correctly analyzed and discussed in a German book written by Barkhausen about 1907 and a good many other recent books, such as Van der Bijls Thermonic Vacuum Tubes, published in 1920.

21. Question. You testified on behalf of the defendant in the case of Peter Cooper Hewitt against the American Telephone & Telegraph Co. involving the Peter Cooper Hewitt patents 781001 and 781002, did you not?

Answer. I did.

22. Question. Will you compare the kind of amplification which you have just described in your answer to question 20, with such amplification as is obtained in the operation of the devices of the two Peter Cooper Hewitt patents, just referred to?

Answer. Any amplification due to the insertion of a mercury vapor arc into a series circuit is simply a case of the negative-resistance type of amplification which I have been describing and discussing in the foregoing. This is the only type of amplification involved in the patents to which you refer.

23. Question. Will you now compare the type of amplification due to a negative resistance, such for example, as that of a gas-filled two-electrode tube of a Peter Cooper Hewitt tube, with the type of amplification obtained by the three-electrode type of tube and state wherein these types of amplification differ from each other?

Answer. They seem to me to be completely distinct in principle. A three-electrode tube such as is used in the modern tube amplifier does not have a negative resistance at all. It amplifies as I have said above, by the relay principle, that is by tapping the energy of an entirely new circuit and multiplying the energy of the signal in any desired amount, up to a thousand or even a millionfold if more than one stage is used. Its immense utility in modern life results from the fact that it is amazingly distortionless and is capable of quantitative analysis and predetermination, with definite amplification coefficients, whereas negative-resistance amplification has thus far been found to be of no commercial value because it lacks completely both these characteristics.

Cross-examination.

By Mr. Peters:

24. Cross-question. What experience have you had with two-electrode vacuum tubes such as that disclosed in the Fleming patent?

[fol. 586] Answer. I have worked with them in the laboratory but have had no commercial experience with them whatever.

25. Cross-question. Where did you obtain those that you worked with in the laboratory?

Answer. Constructed some of them myself, and have had others constructed in the laboratory by the Western Electric Co.

26. Cross-question. How much gas must there be in a two-electrode tube in order that the tube will display what you have termed negative resistance?

Answer. I think that in general any tube operating with a blue glow as it is sometimes called, may exhibit a negative characteristic, to what extent a blue glow is visible, is rather difficult to state, because it depends so largely upon the contrast between the amount of light emitted by the

tube and that coming in from other sources. One's judgment in this matter in an ordinarily lighted room is particularly subject to error. In general, however, to make as specific an answer to your question as I am able, tubes which are working at a pressure as low as 10^{-5} millimeters may be considered as pure electron discharge tubes; that is, they do not give evidence of the appreciable ionization which makes a negative resistance possible. Tubes, however, which have in them the pressure of mercury vapor at ordinary temperatures, which is about 10^{-3} millimeters, will generally show blue glow and may then exhibit the phenomena of negative resistance, when they are operated at high enough voltages. This last statement indicates that the applied voltage as well as the residual pressure as measured before the voltage is applied have to do with the appearance of the large amount of ionization which is essential for the development of a negative resistance. This answer then will perhaps give you the broad limits as to the pressure conditions under which negative resistances may be expected to appear.

27. Cross-question. What was the order of vacuum commercially possible at the date of the Fleming patent?

Answer. 10^{-6} or 10^{-7} millimeters of mercury.

28. Cross-question. Was that the vacuum of commercial electric lamps at the date of the Fleming patent?

Answer. Not at the time at which they were exhausted. I have myself made few, if any, measurements on the vacua obtained in commercial lamps. Doctor Langmuir, however, has stated that in view of the so-called clean-up effects due to the incandescence of the filament, the vacua actually existing in commercial lamps is in general very high.

28½. Cross-question. What type of pumps were available for exhausting vacuum lamps or tubes in 1904?

Answer. Mercury pumps of the Sprengel or Toepler types. These were capable of producing vacua, when used with suitable cooling traps, such as were employed in our laboratory prior to 1900, of the order of magnitude indicated above. I speak with great positiveness on this point, because I myself prior to 1904 had built a pump of this type, with which I have directly measured the vacuum produced only by methods in use prior to 1904, which showed pressures as low as 10^{-6} millimeters. I was myself entirely responsible for the development of high vacuum technic at the University of Chicago, at about this time, and know

that we could produce in 1906 or 1907 at least quite as good vacua as we can attain to-day.

[fol. 587] 29. Cross-question. My question was directed to commercial practice in 1904. Can you not state briefly what was the degree of exhaustion of tubes and lamps and vacuum tubes at that day?

Answer. I have never been very closely in touch with commercial lamp practice, but I should estimate from a knowledge of the kind of pumps that were used, that commercial lamps had been exhausted, before the clean-up effects had operated, to pressures of a thousandth of a millimeters, that is: 10^{-3}.

30. Cross-question. Can you state in a simple way how you would have ascertained a vacuum in any vacuum tube in 1904?

Answer. With a so-called McLeod gauge, which we can use to-day to measure with fair reliability, pressures of 10^{-6} millimeters.

31. Cross-question. Are you familiar with any three-electrode tubes produced prior to those which you say were developed by the Western Electric Co. beginning in the fall of 1911?

Answer. Only with the De Forest tubes.

32. Cross-question. Then your testimony was not given with the understanding that the Western Electric Co. first produced three-electrode tubes?

Answer. Not at all. They first developed the three-electrode tube for the purpose of commercial amplification for use on the telephone lines.

33. Cross-question. Can you state briefly what the development by the Western Electric Co. consisted in?

Answer. That is a question to which I could not give an authoritative answer, but I should say in general that their problem was the adaptation of the three-electrode tube as it had existed before to the entirely new problem of distortionless telephonic repetition or amplification and the modification of designs and conditions of manufacture so as to make it a thoroughly reliable and duplicable device for the purpose in hand. For example, gas in the De Forest three-electrode tube does not seriously impair it as a mere detector. It does render it quite inapplicable for the purposes of distortionless amplification.

34. Cross-question. The gas in the De Forest audion impaired it for distortionless amplification, but it still would

act as an amplifier, would it not on radio telegraph signals?

Answer. Yes; a three-electrode tube may act as an amplifier, even though there is sufficient gas present so that the amplification is not distortionless.

35. Cross-question. Do you know about how much gas there was in the De Forest tubes?

Answer. I do not think that question could be answered by anybody, for I think the De Forest tubes were at that time exceedingly variable in their gas content; some of them acting quite like well-exhausted tubes, and others not.

36. Cross-question. What experience did you have with the De Forest tubes about which you say you knew before the fall of 1911?

Answer. I had no experience with the De Forest tubes before the fall of 1911. Indeed, I think the first one that I saw was some time in 1912.

[fol. 588] 37. Cross-question. You referred in your testimony to the use of the three-electrode tube by the Government during the war as an amplifier; was not such a tube also used at the same time by the Government as a detector?

Answer. I couldn't speak with absolute certainty about that; but I presume that it was to a very considerable extent, although I should have the off-hand judgment that its use as an amplifier was very much larger.

38. Cross-question. When used as a de-ctor a three-element valve acts as a rectifier, does it not?

Answer. Yes; in the sense that it lets through more current in one direction than in the opposite.

39. Cross-question. And it is this rectifying or valve property of the three-electrode tube which renders it useful as a detector of high-frequency waves, is it not?

Answer. Yes; at least in one kind of a detector mechanism, such a one for example, as is used when the Morse signals are being received. This of course does not mean that it could not detect signals in any other way than through this valve or rectifying action, for that would be I think quite contrary to the fact.

40. Cross-question. What other kind of detection have you in mind?

Answer. Such as is used when distortionless speech is transmitted by wire, for example.

41. Cross-question. Are you referring to radio uses or to wire uses?

Answer. Either one.

42. Cross-question. That is to say, if I understand you, that the rectifying property of a valve is not required in receiving distortionless speech transmitted by radio?

Answer. Certainly not for the audio wave, for any valve action on a given wave form necessarily distorts that form.

43. Cross-question. Is not a detector necessary when receiving both radiotelephone and radiotelegraph signals?

Answer. Certainly, if you define detecting as the receiving of a signal.

44. Cross-question. In what sense have you used the word detection in your deposition?

Answer. I defined it at the time at which I used it by explaining quite fully how an electronic valve or rectifier operated in detecting radio signalling; that is, in rendering them either visible or audible. I did not limit of course, all detecting to electronic valves, or rectifiers, nor can it be so limited, as detecting is a very broad term.

45. Cross-question. How does a three-electrode valve operate to detect signals in any other way than through its valve or rectifying action?

Answer. In the ordinary passing of speech from one circuit on to another circuit through the relaying principle, as it is used in the telephone amplifier of the three-electrode type, for example, the amplifier is of course a detector in the broad sense, but if the wave form is transmitted undistorted there is here no rectifying of valve action at all.

46. Cross-question. I understand that you consider an amplifier to be a part of a detector; is that right?

[fol. 589] Answer. Not a part of a detector; all amplifiers are, of course, detectors, in the broad use of the word detection; that is, they transmit and render audible or visible signals, but there are detectors of course which are not amplifiers, for example, the Fleming valve.

47. Cross-question. Can an amplifier be used for receiving any form of radio signals without a rectifier?

Answer. Yes; i. e., without any rectification of the signals.

48. Cross-question. Would the signals be audible without rectification?

Answer. Certainly they could be made so.

49. Cross-question. How?

Answer. By the modulating principle.

50. Cross-question. What principle do you refer to as the modulating principle?

Answer. The term is well known. I can refer you to any book on wireless telegraphy or wire telegraphy.

51. Cross-question. Do you mean that a radio telephone signal modulated to transmit music can be received by an amplifier without being rectified and made audible on the telephone?

Answer. Certainly; for if rectification of the audio wave were essential, it would be completely hopeless to attempt to transmit distortionless speech, since wherever there is rectification there is necessarily distortion of the wave form.

52. Cross-question. You are familiar in a general way with radio-telephone receivers such as are now commonly used for broadcasting reception, are you not?

Answer. Somewhat.

53. Cross-question. They all comprise a so-called detector element, do they not?

Answer. Presumably so; they certainly must detect in the broad sense of the word.

54. Cross-question. And this detector can be a crystal detector, a two-element tube, or a three-element tube, can it not?

Answer. Yes.

55. Cross-question. And without it the receiver would not operate?

Answer. In other words, it can not detect without detection; certainly not.

56. Cross-question. What does the so-called detector element do?

Answer. Receives the signal.

57. Cross-question. Receive the signal and passes it on; but what change does it bring about in the form of the signal current?

Answer. If it operates as a distortionless receiver, no change in the audio-wave form.

58. Cross-question. Why is it necessary to use it at all?

Answer. Because the ear is not adapted to receive electromagnetic waves, for one reason.

59. Cross-question. What does the detector do that enables the ear to receive the signal?

Answer. The whole receiving mechanism in the case of wireless telephony acts in some way to reproduce at the

receiving station the speech wave form sent out at the transmitting station. This wave form is actually carried upon a continuous succession of high-frequency oscillations in ordinary wireless telephony practice, the mechanism by which that wave form is imposed upon the high-frequency [fol. 590] waves at the transmitting end and brought back to the telephone at the receiving end. I do not care to go into it here, since it would be more satisfactory to simply refer to a chapter or two in books on wireless telephony, but the point with which we are here concerned, I take it, is that if the wave form of audio frequency which was impressed at the transmitting end is reproduced without distortion at the receiving end, at no point in the process will there have been rectification of such kind as is produced by a Fleming valve in that audio-wave form, for I repeat, rectification consists by its very definition, in the distortion of the wave form. The essential matter here is that the three-electrode valve when used as an amplifier is not a rectifier at all, as is the two-electrode valve. When used on the straight portion of its characteristic curve, it does not rectify, but it does transmit distortionless speech with amplification if desired. You have touched here one of the most essential distinctions between the three-electrode tube and the Fleming valve. Both of them, of course, are detectors, in the sense that they detect signals of one sort or another. The Fleming valve, however, is merely a detector, while the three-electrode tube may be in addition an amplifier. Using the three-electrode tube on the curved portion of its characteristic, it can act as a valve as does the two-electrode tube; that is, it can magnify one side of the wave and suppress more or less completely the other side. This is why I said that when a three-electrode valve was used merely as a detector, not as an amplifier, a little gas in it is not a disadvantage. I trust that this makes clear the way in which I am using throughout the terms detecting and amplifying. In a word, all receiving devices are detectors, but some types of receiving devices are much more than that, they may amplify as well as detect.

60. Cross-question. Taking a detector pure and simple without amplification, won't you state briefly how it works?

Answer. I refer you to my deposition on the action of the Fleming valve as a detector in the early part of this testimony.

61. Cross-question. And does the three element valve operate the same as a two element valve when used as a detector?

Answer. This is answered in the preceding answer, where I explained as carefully as I can the difference between the three element and two element valves.

62. Cross-question. As an example of the mode of use of the three element valve by the Government, I call your attention to Figure 2 of the drawing marked Miller drawing G, which he says shows a combination of the P-N detector circuit and a two-stage audio-frequency amplifier, are you familiar with this type of apparatus?

Answer. In a general way.

63. Cross-question. Do the three bulbs forming part of this apparatus all operate in the same way?

Answer. That depends upon the structure of the bulbs, and the precise way in which they are used in this circuit and with this last I am not sufficiently familiar to give you a categorical reply. So far as this diagram may be interpreted, the first bulb, that is the one to the left, would seem to be both an amplifier and a detector, and the last two might be said to be used simply as amplifiers if we regard [fol. 591] the detection of the incident wave as having been accomplished when that wave was brought into the receiving apparatus to the left of the line a-b.

64. Cross-question. You state that the first bulb may act both as an amplifier and as a detector, what difference do you have in mind between the two functions?

Answer. Not necessarily any difference, for as I have said a number of times, any bulb that can amplify can of course detect.

65. Cross-question. As another example of the use of these bulbs by the Government, I call your attention to Miller drawing H, inserted at page 97 of the typewritten record, and which shows a six tube apparatus in which the first three of the tubes are marked radio, the fourth tube a detector, and the remaining two tubes audio, what are the different functions of the several tubes employed in this apparatus?

Answer. I have not looked over this part of Doctor Miller's testimony, and would suggest that you can get that information more accurately therefore, from him than from me.

66. Cross-question. I understood that you were familiar with the use of these tubes by the Government?

Answer. In a general way only.

67. Cross-question. Can you refer to any specific use by the Government with which you are familiar?

Answer. I was not in the detail end of the radio work, and my main work in connection with tubes both in my laboratory and out of it has been concerned rather with the interior functioning of electronic tubes than with the details of the circuits with which they are used. I am in general familiar with the tube work which the Government did during the war, in the same way in which I am familiar with the tube development made by the Western and General Electric Cos.

68. Cross-question. I show you a sheet having on it two diagrams, which of either of these arrangements will receive radio telegraph and telephone signals?

Answer. Kindly write a description explaining what those diagrams mean.

69. Cross-question. I have indicated on the sketch the names of the several elements which enter into the apparatus, can you now answer the question?

Answer. Both of them will receive them, but what they will do with them after they receive them, I am not stating.

70. Cross-question. Will they both enable the operator to hear the signal?

Answer. B will not as it is drawn.

71. Cross-question. What does the three element bulb do which enables the circuit A to make the signals audible while the circuit B will not?

Answer. Nothing at all, for neither A nor B will receive them and render them audible as they are drawn, for the reason that, so far as I can see, they contain nothing to transform the radio-frequencies to audio-frequencies.

72. Cross-question. What would you suggest adding to the arrangement in order to make it operative?

[fol. 592] Answer. I shall not attempt to go into drawing a complete receiving system. That can be obtained if you wish it, by consulting Doctor Miller's testimony.

* * * * * * *

73. Cross-question. I call your attention to Miller drawing F, referred to in your answer to question 17, and ask

you to compare Figure 2 with that drawing of Figure A of the sketch referred to in your last preceding answers.

Answer. So far as I can see, the two diagrams are essentially alike, but both of them lack one element which is an essential in some form or other in a three electrode tube in order that it may make the transformation from radio to audio frequency and that element is a leak resistance, which so far as my observation goes it is customary to draw about the condenser which is labeled D3 in the Miller drawing F. Without that leak the grid cannot possibly follow the changes in amplitude of the carrier wave which have been impressed upon it by the audio frequency so that that audio wave form or the envelope of the carrier wave could not be reproduced by an apparatus having the precise characteristics of this diagram. The grid would simply charge up in an apparatus built precisely on these lines to the highest negative potential corresponding to the maximum positive amplitude of the impressed wave form and no lower value of the amplitude would further affect the current from the filament to the plate. This ability of the negative potential of the grid to follow on the average (by virtue of some discharging mechanism such as that which is conventially represented by shunting a high resistance around the grid condenser,) the changing amplitude of the carrier wave which represents the audio frequency, is, I think, essential to the transformation of the radio frequency to audio frequency and therefore to enabling the operator to hear the speech. With the introduction of something to represent the leak from the filament the diagram A represents a device which will enable the operator to hear audio signals. Diagram B, will not permit the operator to hear the signals, unless some more elements are added to it also.

74. Cross-question. All detectors of radio signals must operate as rectifiers, must they not?

Answer. Not in the broad sense in which I have in the foregoing been using the word detector. I was careful to state above that I had been using the word detection in its broad derivative sense i. e. to denote the receipt of a signal of any kind. In technology words often lose their derivative meaning and come to be used in a definite technical sense. It was because I was conscious of the fact that detector was used by wireless men in a very definite and specific sense that I explained from the start that I was not using the word in any such sense, as I have already indi-

cated, I am not at present working in the radio field and have made no claim to intimate familiarity with the multitude of different circuits and arrangement of parts, nor indeed with the technical terms, which are the stock in trade [fol. 593] of the radio engineer. Insofar as I have touched this field in any intimate or thorough going way, it is on the tube side rather than on the circuit side. Reference to Doctor Miller's testimony shows that he uses the word detector not in its broad sense, but in a definite narrow technological sense, and I find that the Institute of Radio Engineers in the report of their committee on standardization for 1915 has given the following technical definition to the word detector, and that Doctor Miller's use of the word appears to coincide with this definition. The definition is as follows:

"Detector: That portion of the receiving apparatus which, connected to a circuit carrying currents of radic frequency, and in conjunction with a self-contained or separate indicator, translates the radio frequency energy into a form suitable for operation of the indicator. This translation may be effected either by the conversion of the radio frequency energy, or by means of the control of local energy by the energy received."

The last sentence shows that the translation of the radio frequency energy into a form suitable for the operation of the indicator may be performed either by the conversion of the radio frequency energy after the manner of the operation of the Fleming valve or by means of the control of local energy by the energy received, after the manner of operation of the three electrode tube as I have described it above. In the sense of the foregoing definition I think I can answer your question by saying that in general under usual operating conditions of radio there must be rectification of the radio frequency energy not of the audio before there can be reception of speech or music by radio. I say, in general, for the reason that for very short distances, speech or music may be transmitted through the ether at its normal frequencies and received in quite the same way in which transmission and reception are accomplished in wire telephony.

75. Cross-question. Using the word "detector" in the sense in which it has been used in the radio art, please state

whether the three-element valve when used as a detector of radio signals acts as a rectifier?

Answer. In general, it does of the radio-frequency.

76. Cross-question. Do you know of any use by the Government where it did not so act?

Answer: I think not.

77. Cross-question. And it is this rectifying or valve property of the three-electrode tube which renders it useful as a detector of high-frequency waves, is it not?

Answer. Yes; in this technical sense, of the word detector.

78. Cross-question. It is true, is it not, that the physical principles underlying thermonic tubes having two electrodes are applicable also to three electrodes?

Answer. Only in the sense that they both utilize pure electron discharges produced by heating a filament to a high temperature in an evacuated tube. In my judgment they involve altogether distinct physical principles in the following important particulars:

The most conspicuous and important element in the three-electrode tube is the operation of changes in the potential of the grid upon what is called the space charge about the filament in such a way as to control the current furnished by a new battery or other source of electrical energy in a circuit containing the filament and the plate. This very important relay principle is the one which it seems to me has [fol. 594] made possible more than 99 per cent of developments of the last 12 years in both wire and wireless telephony and telegraphy. This principle is, in my judgment, entirely wanting in the Fleming valve, which acts as I have before said merely as a rectifier.

79. Cross-question. Is it true that the effect of applying a potential to the grid of the three-element tube is equivalent to the application of a different potential to the plate circuit?

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Answer. It certainly can not be the equivalent in its result, else the grid might be dispensed with, and two electrode tubes used as distortionless amplifiers, for example.

80. Cross-question. Is it your understanding that a three-element valve never has a negative plate resistance analogous to that of which you have spoken in connection with an arc?

Answer. It never has a negative resistance when the volt-ampere characteristic is determined as in the case of the arc

by taking a volt-ampere curve between the filament and the plate, there being always, as in the case of the arc, a direct casual relation between the applied potential and the current produced by it. It is of course possible to interfere with that casual relation by some variable third agency so as to give a negative slope to a volt-ampere curve, but the space between the filament and the plate can not then properly be said, in my judgment, to possess a negative resistance. At any rate, this is something quite distinct from the negative resistance of an arc which is due to copious ionization of gas or vapor molecules.

81. Cross-question. And the third agency which you refer to may be the grid of the three-element tube, may it not?

Answer. One could introduce the third agency through the grid, but again let me say that whenever any such third agency is introduced, the whole significance of the term negative resistance disappears and we begin to confuse so it appears to one sound thinking by the indiscriminating use of words.

82. Cross-question. I call your attention to a book by Lauer & Brown entitled "Radio Engineering Principles," which book contains a "Foreword" of appreciation by Maj. Gen. George O. Squier, Chief Signal Officer of the United States Army, and to a statement on pages 177 and 178, which reads as follows:

"If now the grid potential Eg is varied so as to increase the current Ip in the plate circuit, it is seen that the resistance drop rIp in the external plate circuit will correspondingly increase. It then follows from equation (30) that, with the battery voltage Eb remaining constant, the plate potential Ep will decrease. Conversely, if the current Ip is decreased by decreasing the grid potential, the plate potential Ep will increase. Thus, on account of the external resistance of the plate circuit, the plate potential is no longer constant, but is a function of the plate current, and varies in opposite direction to the latter. In other words, the tube, operated under such conditions, has a negative plate resistance reaction as defined in connection with the oscillating arc, Chapter V. This will be taken up in greater detail in a later paragraph."

[fol. 595] Do you agree with that statement?

Answer. I couldn't answer that question without more careful study of the whole argument than I can make here.

I should wish to understand the author's terminology and his definitions before saying that he was right or wrong.

83. Cross-question. You do not deny these statements made in the quotation on any knowledge which you now have on the subject?

* * * * * * *

Answer. I am confident that the author and myself could entirely agree on this matter if we were to get together on our definitions, but it is quite impossible to take a single short paragraph which presupposes much that has gone before and refers as this paragraph does, to much that is to follow, and say that one disagrees with it or agrees with it.

84. Cross-question. As I understand you, a device displays the property which you call negative resistance when its current and voltage vary inversely?

Answer. Yes; provided the current and voltage are casually related.

85. Cross-question. Do any of the curves of Figure 75 on page 153 of the Vander Bijl book to which you have referred show this negative resistance property; and if so, which?

Answer. I should have to make the same reply as I made before, that it will be necessary for me to understand precisely what these curves represent better than I can by merely looking at the diagrams, to say whether they do or do not show a negative resistance. My off-hand impression would be that they do not, because they are labeled grid amperes and grid volts, and I suspect, therefore, that they represent volts and amperes which are not casually related. At any rate, the phenomenon is quite distinct from that found in the arc unless the negative slope is due to the copious ionization of a gas or vapor.

86. Cross-question. What would be casually related to grid currents, if not grid voltage?

Answer. The volts and amperes would be casually related if a battery were attached simply between the filament and the grid, no current at all going to the plate, and the volt ampere curve then taken. If the amperes then increase with decreasing voltage, no other causes influencing the flow of current between filament and grid except the applied potential between filament and grid, the resistance would be negative, and the properties or characteristics, by whatever

words we describe them, would then be like those of a gas filled Fleming valve, otherwise not.

87. Cross-question. According to your definition, then, the signal received by the grid and the signal given out by the plate circuit are not casually related?

Answer. This is another matter entirely; we haven't been talking about signals given out by the grid, or the plate; you have merely asked me for the definition of negative resistance, and I have attempted to give it.

88. Cross-question. And the current shown in Figure 75 is not caused by the voltage applied?

Answer. I don't know.

[fol. 596] 89. Cross-question. I call your attention to Figure 16, page 48, of the Vander Bijl book and to the last paragraph on page 49 and ask if this referes to the three-element bulb?

Answer. Figure 15 looks like a three-element bulb. I do not know what Figure 16 does represent, nor do I know what definitions Vander Bijl has here set up.

Redirect examination.

By Mr. Edwards:

90. Redirect question. If the three-electrode tube is employed in an amplifier circuit, does it act as a detector, defining detector as you have done in your answer to cross-question 74?

Answer. If the amplifier is merely producing distortionless amplification, there is none of the rectification quality present, which is necessary for the transformation of a radio frequency into an audio frequency, such as the definition requires.

Recross-examination.

By Mr. Peters:

91. Recross-question. When a three-element bulb is used on an amplifier, it is unilaterally conductive, is it not, for any grid current, which flows onto the plate current?

Answer. When it is functioning as a pure amplifier, the wave form coming in from the line is reproduced in all its phases with their relative values unchanged. This alternating wave from is superimposed upon a continuous

unidirectional current through the plate battery circuit. It is this last current alone which, as it seems to me, can be properly called unilateral. The signaling current is sent out with just the wave form with which it came in.

92. Recross-question. Is maximum amplification consistent with distortionless amplification?

Answer. I do not know quite what you mean by maximum amplification, for there is theoretically no limit to amplification, and therefore no such thing as a maximum of amplification.

93. Recross-question. My question was directed to the possibility of practical apparatus, and not to mere theories; with such practical apparatus as we have been discussing, is maximum amplification possible or consistent with distortionless amplification?

Answer. The practical limit is imposed by the bothersomeness of the extraneous noises originating in the microphone or elsewhere, which are magnified quite as much as the speech so that the distortion of the wave form is not, I think, the actual practical difficulty in amplification.

(The examination by counsel being concluded, the witness, in compliance with the rule of the court requiring him to state whether he knows of any other matter relative to the claim in question, and if he does to state it, says he does not.)

It is hereby stipulated, subject to correction should error appear, that the annexed copies of depositions of Joseph B. Baker and John Stone Stone, and the exhibits referred to therein, are true and correct copies of depositions given by the said Baker and the said Stone, and the exhibits introduced in connection with said depositions, given on the 28th and 29th days of February, 1916, in the case of the Marconi Wireless Telegraph Co. of America against Kil- [fol. 597] bourne & Clark Manufacturing Co., in the United States District Court for the Western District of Washington, Northern Division; and that said copies of said depositions and exhibits may be received in this cause as the depositions of the said Baker and the said Stone with the same force and effect as if said witnesses had been duly called, sworn, and examined on behalf of the defend-

ant in this cause, and the said depositions taken and exhibits duly introduced herein. The said exhibits which in said depositions are designated as "Defendant's Exhibits Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10," shall be marked in this case as "Defendant's Exhibits E-3 to N-3," inclusive, respectively. The exhibits offered by plaintiff in said Stone deposition and marked therein as "Plaintiff's Exhibits A, B, and C" shall be marked in this cause as "Plaintiff's Exhibits 120, 121, and 122," respectively.

It is further stipulated, subject to correction should error appear, that the said John Stone Stone and Joseph B. Baker were called as witnesses on behalf of the defendant in the suit of the Marconi Wireless Telegraph Co. against the Alantic Communication Co. in the United States District Court for the Eastern District of New York, on or about May 14, 1915, and there identified the originals of the aforesaid Exhibits E-3, F-3, and G-3, which said originals were offered in evidence in said cause.

And it is further stipulated that if the said John Stone Stone and Joseph B. Baker were called as witnesses in this case, they would testify that the aforesaid Exhibits E-3, F-3, and G-3 are correct copies of the said original exhibits (being the said letters from Baker to Stone, dated July 22, 1899; from Stone to Baker dated June 30, 1899, and Stone to Baker dated July 18, 1899).

And it is further stipulated that the aforesaid Exhibits E-3, F-3, and G-3 may be received in this cause with the same force and effect as the originals of said letters, all objection to the competency thereof being waived.

And it is further stipulated that the annexed is a true copy of the deposition of Walter C. Dean, who testified as a witness on behalf of the defendant in the aforesaid case of the Marconi Wireless Telegraph Co. of America against the Atlantic Communication Co. in the District Court for the Eastern District of New York, and that the said copy may be received in evidence on behalf of the defendant in this case with the same force and effect as if the said Walter C. Dean had been duly called as a witness on behalf of the defendant, sworn, and testified, as stated in said deposition: and it is further stipulated that the annexed is a true copy of the defendant's Exhibits F-3, referred to in said Dean deposition, and that the same may be marked as "Defendant's Exhibit O-3" in this case, and

received with the same force and effect as the original of said exhibit.

Dated January 19, 1924.

Sheffield Betts, L. T. H. Betts, Attorneys for Claimant. Clifton V. Edwards, Attorney for Defendant, Special Assistant to the Attorney General.

Approved:

Robert H. Lovett, Assistant Attorney General.

[fol. 598] New York, February 28, 1916.

Proofs for final hearing taken on behalf of defendant at the office of George F. Scull, Esq., 149 Broadway, New York City, before Alexander Gilchrist, jr., standing examiner in the United States District Court, Southern District of New York (acting as examiner by agreement of parties in the place and stead of Thomas B. Hardin, Esq., named in said order, the latter being incapacitated by illness) pursuant to an order herein dated February 17, 1916, and to notice to plaintiff's counsel thereunder, beginning February 28, 1916, at 10:30 a. m.

Appearances: L. F. H. Betts, Esq., counsel for the plaintiff; George F. Scull, Esq., counsel for the defendant.

Joseph B. Baker, a witness called on behalf of the defendant, being duly sworn, deposes and says in answers to interrogatories as follows:

Direct examination.

By Mr. Scull:

1. Question. Where do you reside, Mr. Baker?

Answer. New York City.

2. Question. Are you acquainted with Prof. John Stone Stone?

Answer. Yes, sir.

3. Question. Please state how long you have known him and the circumstances connected with your acquaintance with him.

Answer. I met Mr. Stone in the year 1891. At that time he was employed in the mechanical department of the

American Bell Telephone Co. in Boston, and I was employed in that year in the same department. We were both engaged in experimental work, for the telephone company and Mr. Stone and I became quite intimate, especially in connection with his own inventive work both for the telephone company and later on in his own interest.

4. Question. How long did your acquaintance with Professor Stone continue, roughly? By that I mean your acquaintance with him while you were in Boston.

Answer. It continued from 1891, or some time in 1891, to the time I left Boston to go to Schenectady to take a position with General Electric Co. there, which was in the year 1904. That was my active acquaintance with Mr. Stone in Boston.

5. Question. Were you acquainted with any work which Professor Stone did in radiotelegraphy?

* * * * * * *

Answer. Yes, sir.

6. Question. Were you acquainted with any ideas that he had in connection with radiotelegraphy?

Answer. Yes, sir.

7. Question. Have you previously testified in a suit in the United States District Court for the Eastern District of New York, entitled "Marconi Wireless Telegraph Co. of America *v.* Atlantic Communication Co., and others," [fol. 599] in which you testified for the defendant and were cross-examined by Mr. L. F. H. Betts?

Answer. I testified in a suit some months ago in Brooklyn, and I believe that was the suit.

Mr. Scull. It is agreed that the suit referred to was based on Marconi patent No. 763772 and Lodge patent No. 609154.

8. Question. I show you a paper and ask you if you know what that is?

Answer. I believe this is a letter that I wrote to Mr. Stone acknowledging communications from him.

9. Question. Is it an original or a reproduction?

Answer. I believe it is a reproduction.

10. Question. When you testified in the Brooklyn suit to which I referred above, were you shown the original of this letter?

Answer. Yes, sir.

Mr. Scull. I offer this in evidence and ask that it be marked "Defendant's Exhibit No. 1."

* * * * * * *

Mr. Scull. Defendant's counsel states in reference to this exhibit and others, which will be produced hereafter, that the originals thereof were introduced in evidence in the suit against the Atlantic Communication Co. above referred to, and are there part of the court records, and not available to this defendant, although they might be available to plaintiff's counsel.

(Marked "Defendant's Exhibit No. 1.")

11. Question. I show you two papers and ask you if you recognize them?

Answer. I do recognize these papers.

12. Question. Will you briefly state what they are?

Answer. I believe these papers are reproductions of letters which were written to me by Mr. Stone on the dates given at the heads of the letters, in which he disclosed to me certain ideas which he had in regard to selective wireless telegraphy.

13. Question. Are these letters the letters referred to in your letter of July 22 as you now recall?

Answer. Yes, sir, they are the letters that were acknowledged in my letter of July 22.

Mr. Scull. I offer in evidence the reproduction of the letter dated June 30, 1899.

* * * * * * *

(Marked "Defendant's Exhibit No. 2.")

Mr. Scull. I also offer in evidence the second paper referred to, being letter dated July 18, 1899.

* * * * * * *

(Marked "Defendant's Exhibit No. 3.")

14. Question. Do you now recall the receipt of these letters and your sending the acknowledging letter, defendant's Exhibit No. 1?

[fol. 600] Answer. I recall the fact of receiving them and acknowledging them. I do not recall the detail local circumstances.

15. Question. I note on defendant's Exhibit No. 1 that the date "20th" has been stricken out and "June 20," written above the same. Can you explain this?

Answer. This letter was dictated to a public stenographer in Boston. I made use of that stenographer in my own inventive work in correspondence and she wrote a good many letters and papers for me. I recall that it was my habit in reading over her work to make the corrections with a pen as I read the letter or the paper, and then to sign it afterwards, and to the best of my recollection I made this correction, noting that the date was wrong, but apparently in seeking to make the correction I made another error, but my intention was to have the dates in this acknowledgment correspond to the dates of the letters that I had received from Mr. Stone.

15. Question. In addition to the receipt of these letters, did you have any conferences or conference with Professor Stone on the subject matter referred to in these letters?

Answer. Yes, sir; there were several such conferences.

16. Question. Up to the time of these conferences what had been your training generally, and particularly in the subject of electricity?

Answer. I had been educated at the Massachusetts Institute of Technology in the course of electrical engineering, graduating in 1890 with the degree of S.B. Following that technical-school training I had been connected with an electric-light contractor for one year, which brings me up to 1891. From 1891 to 1898 approximately I was connected with the American Bell Telephone Co. and with the American Telephone & Telegraph Co. In all of these occupations I endeavored to keep abreast of the times in electrical invention and discovery, and through my association with Mr. Stone I became fairly well acquainted with the art of wireless telegraphy as it was practiced at that time.

17. Question. These conferences that you had with Professor Stone, were they prior to or subsequent to the writing of these letters, defendant's Exhibits Nos. 1, 2, and 3?

Answer. To the best of my recollection they were both prior to and subsequent to these letters.

18. Question. Please state as well as you can now recollect what Professor Stone then explained to you as his inventions.

Answer. If I may be a little discursive in this matter: Stone and I were great friends, and when he had an idea he would communicate with me about it, and when I had an idea I would communicate with him. We talked things over in a mutual helpful way. It was quite a regular thing for me to meet him by appointment for lunch or at his office and for him to sit down and make a little diagram, write a few equasions, to explain an idea that had come to him. Sometimes these conversations would last for hours, and he would bring out one idea after another, illustrating them with diagrams, working them out, largely, at that interview, I believe. In this way he disclosed to me certain ideas in regard to the improvement of wireless telegraphy, the majority of his ideas being based upon his mathematical researches. Among the ideas that he disclosed was the fact that a vertical wire had a natural period of oscillation of an electric charge impressed upon it, and [fol. 601] that it could be made the seat of a set of electrical oscillations of different frequency, which Stone called forced oscillations or forced vibrations. Another point that he mentioned was the extreme desirability of developing a continuous train of electromagnetic waves other than the spark gap, which was the means then used.

Another point that he often discussed was the great necessity for improvements in the coherer, the coherer being the only device known at that time, as far as I am aware, for receiving wireless telegraph sendings. These points are representative of a number of points that he brought up. I might add that the whole burden of his work was the desirability of selective wireless telegraphy. He realized that it was very important that messages should be secret, and that they should be as secured from interruption as wireless telegraph messages are, whereas at that state of the art they were not at all secured from interruption and not at all secret.

19. Question. Referring to this matter of selectivity to which you have referred, did Mr. Stone, as you now recall, explain what he had in mind as a means by which this selectivity would be obtained generally?

Answer. Yes, he did.

20. Question. What do you now recall that to be?

Answer. I recall very distinctly that his idea was—Mr. Stone's idea was to provide a circuit at the sending station and a circuit at the receiving station such that the electrical oscillations of a certain determined frequency would flow in the circuits at maximum strength of current, and oscillations of all frequencies would be, I might say, discouraged; they would find these circuits more or less opaque.

21. Question. What do you now recall was Professor Stone's idea as to how he expected to determine the frequency of his waves?

Answer. I recall that point distinctly also. He explained to me that the natural rate of vibration of any electric circuit was due to the elements of electrostatic capacity and inductance, and he proposed to control the periodicity of the oscillations in his circuits by regulating the value of the capacity and the value of the inductance by suitable condensers and inductance coils without iron, and he laid great stress upon the fact that inductances in wireless telegraph work would always have to be without iron on account of the high frequency of the oscillations. I might add that my memory is very vivid on the generalities of this experience, because it formed such a large part of my life. I was quite intimate with Mr. Stone, and it was a great interest in my life, and is at this time, to go into these problems.

22. Question. Referring to these various conversations which you had, what relations, if any, is there between them and these letters, defendant's Exhibits 1, 2, and 3?

Answer. I should say the relation is the letters are a written record of the spirit of many of these conversations and that they were written to me as a means of getting the facts that he had disclosed to me upon record, and securing acknowledgment from me.

23. Question. Do you understand that they are a record of all that he disclosed to you, or merely of the substance of these various conferences and disclosures?

Answer. They are not a record of all that he disclosed to me, neither are they a record of the substance, but I should say that they are a record of some of the or perhaps most of the essential points.

[fol. 602] 24. Question. You say that Mr. Stone frequently made sketches illustrating what he was describing to you. Could you visualize any of the sketches which you used at that time?

Answer. Yes, sir.

25. Question. I show you a certified copy of a photographic copy from the Patent Office records, and ask you if you recognize these sheets that are reproduced photographically?

* * * * * * *

Answer. I believe that this is a copy of the affidavit that I made for the company that Mr. Stone was connected with.

26. Question. Would you recognize that signature as a photograph of your signature [indicating]?

* * * * * * *

Answer. I believe that that is a reproduction of my signature.

27. Question. Do you remember that on or about the date of this paper, March 18, 1901, that you made an affidavit of that character [indicating paper]?

* * * * * * *

Answer. I remember making one or two or three affidavits. I do not remember when they were made.

28. Question. Were the affidavits you just referred to in your last answer made before or after the sending of these letters, defendant's Exhibits 1, 2, and 3?

Answer. To the best of my recollection, all the affidavits were made after the letters and my acknowledgment of the letters.

29. Question. What was the subject matter of these affidavits you said you had made, generally speaking?

Answer. Speaking very generally, the subject matter was to fix the date of Mr. Stone's disclosures to me.

30. Question. And did they or did they not refer, as you now recall, to these letters, defendant's Exhibits 1, 2, and 3?

* * * * * * *

Answer. I believe that they all referred to these letters.

Mr. Scull: I offer in evidence the certified copy of the affidavit, dated March 18, 1901, and ask that it be marked "Defendant's Exhibit 4."

* * * * * * *

Mr. Scull: Defendant's counsel notes that this paper is shown the witness merely for the purpose of connecting his signature thereon with the matters to which he has testified, and that defendant expects to offer in evidence sub-

sequently a certain copy of the file wrapper of patent No. 714831.

(Marked "Defendant's Exhibit No. 4.")

31. Question. I note in this affidavit you state, "Also prior to the time above named I wrote and mailed to Mr. Stone a letter in which I stated that I had received his description and understood it and believed myself capable [fol. 603] of putting the same in practice." Can you now state to what sentence that letter refers?

Answer. I believe it refers to this letter which I have spoken of before.

32. Question. Referring to defendant's Exhibit 1?

Answer. Yes.

33. Question. I show you a paper parporting to be a photographic copy of an affidavit and ask you if you recognize that?

* * * * * * *

Answer. I believe it is a reproduction of an affidavit that I made.

34. Question. Do you recognize the reproduction of the signature?

Answer. Yes, sir.

35. Question. What is that?

Answer. It is a reproduction of my own signature, I believe.

36. Question. With your memory refreshed by this photographic copy, can you not state whether or not you made an affidavit on or about the date specified therein, and generally what such affidavit related thereto?

* * * * * * *

Answer. I remember making affidavits, but I do not remember the dates, nor do I remember how many there were.

37. Question. When you say "I remember making affidavits," what do you mean?

Answer. I remember being requested to come to the office of the Stone Wireless Telegraph & Telephone Co. and having them present to me affidavits drawn up ready to be executed and being requested to read them and execute them, and I remember that I did read these documents at the time, and satisfied myself that they were substantially correct, and that I was willing to swear to the truth of their contents.

38. Question. Generally what was the subject matter of these affidavits that you have referred to?

Answer. The fact of the disclosure to me of certain ideas in wireless telegraphy by Mr. Stone.

39. Question. I note in this copy which I have shown you there is this statement:

"Prior to December 15, 1899, I received from Mr. Stone two letters containing a full and complete written description with drawings of a system of selective electric signaling by simple harmonic electromagnetic waves.

"Also prior to December 15, 1899, I wrote and mailed to Mr. Stone a letter, in which I stated that I had received his description and understood it, and believed myself capable of putting the same in practice."

Can you tell me to what letters those statements refer?

• • • • • • •

[fol. 604] Answer. I believe they refer to the two letters to which I have already referred.

40. Question. Referring to defendant's Exhibits 2 and 3?

Answer. Yes, and to my acknowledgement of those letters.

41. Question. Defendant's Exhibit 1?

Answer. Yes, sir.

42. Question. Do you know of any letters, other than defendant's Exhibits 1, 2, and 3, which passed between yourself and Professor Stone relating to the subject matter in the two paragraphs which I have quoted to you from this affidavit?

Answer. No, I do not recall any other letters.

Mr. Scull. I offer in evidence the two sheets of photographs shown the witness and ask that the same be marked "Defendant's Exhibit 5."

• • • • • • •

Mr. Scull: For information of plaintiff, defendant's counsel advises plaintiff's counsel that the papers shown this witness have not been for the purposes of proving that any such affidavits ever were filed, but rather to show what was disclosed to this witness at various times, and to show furthermore that this disclosure was referred to subsequently by this witness long prior to any controversy arising over the subject matter of the patent in suit.

(Marked "Defendant's Exhibit No. 5.")

Cross-examination.

By Mr. Betts:

43. Cross-question. You state that you were connected with the Bell Telephone Co. and the American Telephone & Telegraph Co. from 1891 to 1898?

Answer. Yes, sir.

44. Cross-question. What were your duties during that time?

Answer. My duties for the American Bell Telephone Co., where I was employed from 1891 to about 1894, were to prosecute experimental work in the experiment laboratory [fol. 605] of that company, and to pass upon the inventions of outside inventors which were submitted to the company; also to make routine tests of copper wire used in stringing the lines of the telephone company; and other work ordinarily carried on in the experiment laboratory. My work for the American Telephone & Telegraph Co. was that of an inspector and of a service inspector. It consisted in the construction, care, and maintenance of switchboards, line construction work, and research work connected with traffic problems.

45. Cross-question. Then all of your work while you were connected with either the Bell Co. or the A. T. & T. Co. was in connection with wire telephony?

Answer. All of my work with those companies was in connection with wire telephony.

46. Cross-question. How old were you in 1899?

Answer. I was about 30 years of age.

47. Cross-question. You stated I believe that as far as possible you kept up with wireless telegraphy as practiced prior to 1899. What was wireless telegraphy as practiced prior to that date?

Answer. Well, to begin with, it was very meager. It was associated with the name of Mr. Marconi largely, but other inventors were coming into notice. It consisted of the sending and receiving of messages from untuned stations, received from untuned stations, over comparatively short distances, and the essential apparatus consisted of a spark gap connected to a vertical wire at the sending end and at the receiving end a coherer connected to the vertical wire.

48. Cross-question. What wireless stations had you personally seen prior to 1899?

Answer. I had only seen one actual working wireless station, and I do not know whether that was before or after 1899, but it was about that time. The wireless station I refer to was on the island of Nantucket, a Marconi station which was set up Siasconsett for the purpose of demonstrating that telegraphy could be carried on with ships at sea, and I was present on the island of Nantucket at the time that the *Lucania* was picked up, as it was called, as she was passing, I think on her western trip, at a point 30 or 40 miles distant from this wireless station.

49. Cross-question. How long were you at this wireless station?

Answer. I visited that wireless station once or twice and was present only a few hours.

50. Cross-question. Is that then all the practical experience you have had in wireless telegraphy prior to 1899?

Answer. I do not recall any other.

51. Cross-question. What was Mr. Stone's occupation with either the Bell Co. or the A. T. & T. Co. while you were connected with those two companies?

Answer. Mr. Stone's occupation, as I recall, consisted of experimental work in part, but very largely mathematical research and inventive work of his own for the company. He devised and recorded a number of inventions connecting the carbon battery system, as it was termed, but spent I suppose the larger part of his time in mathematical research, a comparatively small amount of time in experimental work and in inventive work. I should say the overwhelming majority of his time was spent in mathematical research.

[fol. 606] 52. Cross-question. How long were you and Mr. Stone associated with the Bell and the A. T. & T. Cos.?

Answer. We were together in the Bell laboratory, as it was called, from 1891 to approximately 1894. We were then separated, from the fact that I went with the other company, the American Telephone & Telegraph Co., and he remained with the American Bell laboratory, so that that was the period of our association, simply this three years approximately, the period of our association with the same company. Later on I think he was retained by the American Bell Telephone Co. during the time that I was employed by the American Telephone & Telegraph Co. I believe he was retained by the telephone interest, but which company I am not quite sure.

53. Cross-question. I believe you stated that Professor Stone not only disclosed to you his selective system but also ideas that he had in coherers and other devices for wireless telegraphy; is that correct?

Answer. Yes, sir.

54. Cross-question. Can you positively swear that the letters marked "Defendant's Exhibits 1, 2, and 3," are the only letters which passed between you and Stone in regard to all improvements which he made in wireless telegraphy?

Answer. No, sir, I can not.

55. Cross-question. Can you swear that these letters, defendant's Exhibits 1, 2, and 3, are the only letters which passed between you and Stone relating to what you have termed his (Stone's) selective system of wireless telegraphy?

Answer. No, sir, I can not.

56. Cross-question. When first did Mr. Stone, according to your recollection, disclose to you what you have termed Stone's selective system of wireless telegraphy?

Answer. To the best of my recollection it was some years before these letters passed that Mr. Stone commenced to talk to me about his general ideas.

57. Cross-question. Can you give any definite time or place when he disclosed his ideas to you on his so-called selective system of wireless telegraphy?

Answer. I can say this, that it was at or shortly prior to the time that Mr. Stone took an office of his own as a consulting electrical engineer. If that date could be fixed it would help.

58. Cross-question. But I am asking you if you can now place or fix any definite time when he first disclosed to you his selective system?

Answer. No, sir, I can not.

59. Cross-question. Can you fix now any definite time or place at which Mr. Stone explained his ideas to you on his selective wireless system of telegraphy?

Answer. No, sir. His ideas were given to me in fragmentary form from time to time, I believe, as they occurred to him. They were given in the course of informal conversations, many of them.

60. Cross-question. Prior to 1900, besides visiting the Marconi station at Nantucket, what knowledge had you had on wireless telegraphy?

Answer. Only the knowledge that I obtained from reading technical press, which gave rather full reports of what was being done in wireless.

[fol. 607] 61. Cross-question. How frequently did you see Mr. Stone between 1891 and 1904?

Answer. Every day—between 1891 and 1894?

62. Cross-question. No.; 1904?

Answer. Oh, I beg your pardon; between 1891 and 1894 I saw him every day, because we were in the same laboratory. For a few years after 1894 I saw him two or three times a week. It was his habit in coming to lunch, he would come up past the telephone company's building on Milk Street, and quite often stop in for me, and we would go out together. I should say two or three times a week would be a conservative statement.

63. Cross-question. During the years 1898 and 1899 you did not have the same offices with Professor Stone.?

Answer. No, sir.

64. Cross-question. How frequently during those years do you think you saw Mr. Stone?

Answer. I should say two or three times a week, on the average. There would be, as I recall, several weeks go by that I would not see him. Then I would see him every day for a while.

65. Cross-question. Principally at luncheon hour?

Answer. I think so; but I also saw him for long periods at his home or at my home. We used to spend long evenings together.

66. Cross-question. During what years?

Answer. During those years, around 1899 and 1900, as I recall it.

67. Cross-question. In this paper marked "Defendant's Exhibit 5," purporting to be photographic copy of affidavit made by you, you state that you received from Mr. Stone descriptive drawings "of a system of selective electric signaling by simple harmonic electro-magnetic waves." What do you mean by "simple harmonic electro-magnetic waves?"

Answer. I mean an alternating electromagnet wave which is governed by a simple mathematical equation. Such a wave, if plotted graphically, would take the form of a sine curve.

68. Cross-question. On what do you base your belief that defendant's Exhibits 1, 2, and 3 are the letters to which you refer in defendant's Exhibit 5?

Answer. I base my belief upon a general recollection of the contents—no, I will not say the contents—of the trend of the information conveyed, upon a recollection of the fact that such letters passed between us, and of the importance that Mr. Stone associated with getting the matter upon record, and I also base my belief upon a memory of the physical appearance of the letters. I remember perfectly that there were such letters, that I read them carefully, studied them, in fact, and in my endeavor to help Mr. Stone I pretty carefully framed my own reply. I was myself engaged in inventive work at the time, and my mind was full of getting things upon record exactly, with the proper dates.

69. Cross-question. Why did you want to help Mr. Stone?

Answer. We were friends and I was impressed by his genius and foresight in this art. I felt that the work that he was doing was exceedingly important, and I felt honored that I should be one associated with him, and wanted to help him all I could.

70. Cross-question. Referring to defendant's Exhibit 4, what letter do you refer to in that affidavit?

[fol. 608] Answer. Well, I believe I referred in this affidavit not to a letter but to the description embodied in both letters. One letter was supplemental to the other. I remember that I acknowledged both letters by one acknowledgment.

71. Cross-question. Which two letters?

Answer. The two letters that I have referred to in this testimony.

72. Cross-question. (Handing witness papers.)

Answer. I believe that those are the letters.

73. Cross-question. Referring to defendant's Exhibits 2 and 3?

Answer. Yes, sir.

74. Cross-question. On what do you base your belief that defendant's Exhibits 2 and 3 are the letters to which you referred in defendant's Exhibit 4?

Answer. Because as far as I know Mr. Stone attached great importance to those letters and to my acknowledgment of them, and considered them to be a very vital record of his inventive work, and they were considered very important by his business associates; and also to the fact that I do not recall that any other letters were sent to me or that I acknowledged any other letters. Most of the disclosures

were made informally, without a written communication, which was acknowledged. They were simply sketches made in the course of conversation.

75. Cross-question. I believe you stated that as you understood Mr. Stone's disclosure and ideas with respect to his selective system, referred to in defendant's Exhibits 1, 2, 3, 4, and 5, that it was to impress on the antennae forced oscillations. Am I correct?

Answer. Forced oscillations were discussed, but the development of free oscillations was also discussed. The desirability of impressing upon the vertical wire the oscillations which were in its own natural period, that was discussed as well as the impressing upon the vertical wire of forced oscillations foreign to its natural period. It does not come to me now that Mr. Stone made a great point of the desirability of using forced oscillations. It does come to me according to my recollection that he considered the desirability of utilizing the natural period of the vertical wire, and associated with it a circuit which would favor those oscillations; but he did unmistakably speak of the possibility of impressing upon any vertical wire any desired periodicity; he certainly did.

76. Cross-question. That "second circuit" to which you have referred, Mr. Stone called his weeding-out circuit, did he not?

Answer. No, sir. I do not know that I quite understand your question.

(Question read.)

Answer. You used the term "second circuit"?

77. Cross-question. Yes.

Answer. In my answer I referred to a circuit associated with the circuit wire, I believe. That circuit was not the weeding-out circuit. That circuit was the circuit containing inductance and capacity designed to control the periodicity of the oscillations. The weeding-out circuit was a separate circuit.

78. Cross-question. Referring to defendant's Exhibit 1, where were you when you dictated and signed that letter [handing paper to witness]?

[fol. 689] Answer. I was in the office of the public stenographer in the Tremont Building at Boston at the time I dictated it, I believe. I dictated most of my letters in her office,

all of them as far as I recall. I do not recall where I was when I signed the letter.

79. Cross-question. How did you happen to dictate this letter to a public stenographer in the Tremont Building?

Answer. Because it was my habit to dictate a number of papers forming a record of my own inventive ideas—I was using this stenographer, and found it convenient to dictate my letters to her as well.

80. Cross-question. Was Mr. Stone present when you dictated this letter, defendant's Exhibit 1?

Answer. He was not, as far as I recall.

81. Cross-question. Was he present when you signed that letter?

Answer. He might have been, although I doubt it. I probably carried that letter home with other material that the stenographer had written for me and signed it in my home and mailed it. I do not recall.

82. Cross-question. At the time you dictated defendant's Exhibit 1, did you have before you defendant's Exhibits 2 and 3?

Answer. I believe that I did. I had studied them carefully.

83. Cross-question. You say you believe you did. I want to know definitely whether you had these two letters, defendant's Exhibits Nos. 2 and 3, at the Tremont Building when you dictated defendant's Exhibit No. 1?

Answer. I can not recall at all about that. It is possible that I made notes, in studying Mr. Stone's letters, and dictated my letter to the public stenographer in the Tremont Building from my notes rather than having the letters themselves before me. It is possible that that occurred. I remember that I framed my own acknowledgment pretty carefully.

84. Cross-question. But you do not recall whether you signed this letter, defendant's Exhibit No. 1, at the Tremont office building or at your home?

Answer. I do not recall, and yet I might have signed that in Mr. Stone's office. You see, his office was right across the street.

85. Cross-question. I want to know, please, the place, if you can recall it, where you signed this letter, defendant's Exhibit No. 1?

Answer. I do not recall that, sir.

86. Cross-question. Referring to defendant's Exhibits Nos. 2 and 3, there does not seem to be any address contained in either of them. Where were they addressed to?

Answer. I do not recall whether Mr. Stone handed them to me or whether they were mailed to me. I recall that I received them.

87. Cross-question. Did he hand these two letters to you, or did he mail these two letters to you at the same time?

Answer. No, sir.

88. Cross-question. Or were they received separately by you?

Answer. To the best of my recollection they were received separately. I firmly believe that they were received separately.

89. Cross-question. Referring to defendant's Exhibit No. 1, was the interlineation "June 20" made by you?

Answer. Yes, sir; made in my own handwriting.

90. Cross-question. Was this interlineation "June 20" made by you at the same time that you signed your name to this letter?

[fol. 610] Answer. It certainly was. I am positive on that point.

91. Cross-question. Was this interlineation made with the same pen and the same ink that you used in signing this letter?

Answer. Yes, sir. I have no reason to doubt that it was. I do not recall that.

92. Cross-question. Did you use blotting paper at the time you made this interlineation "June 20," in blotting this correction?

Answer. I do not believe I did.

93. Cross-question. Did you use blotting paper after affixing your signature to defendant's Exhibit No. 1?

Answer. Yes, sir. It was my habit to blot my signatures. They were made with a heavy stub-pen, and so much ink that they had to be blotted.

94. Cross-question. Was the interlineation "June 20" on defendant's Exhibit No. 1 made with a blunt pen?

Answer. I believe so—a stub pen. I was in the habit of using a stub pen.

95. Cross-question. How do you account for the fact that you blotted the signature on defendant's Exhibit No. 1 and did not blot the interlineation "June 20"?

Answer. That comes to my recollection pretty well. It

was my habit to read over papers and make corrections with my pen as I read. Many of the things that I dictated were long documents, memoranda of my own experimental work, and I would correct the stenographer's errors or make changes of my own as I went along, and I did so in this case. I applied what I thought was a correction, and then when I got to the end and signed the letter I blotted the signature and probably blotted the other, but the ink had already dried.

96. Cross-question. You now think, then, that you blotted both the signature and the interlineation on defendant's Exhibit No. 1?

Answer. I think that I applied the blotting paper to both, unless I may have noted that the other had already dried.

97. Cross-question. Where was the original of this letter, of which defendant's Exhibit No. 1 purports to be a copy, from the time you wrote it until you identified it in court?

Answer. I do not know. I presume in Mr. Stone's possession.

98. Cross-question. These two letters, defendant's Exhibits Nos. 2 and 3, which you received from Stone, where were the originals of those letters after you received them and until you identified the originals in court in the Atlantic Communication case in Brooklyn?

Answer. They were in my possession for a while. My recollection is that Stone asked me to return them to him, just when I do not know. It might have been a few months afterwards. I think it was not long after I received them.

99. Cross-question. What do you mean by "not long"?

Answer. A few months. My recollection is that he asked for them back again because they were pretty carefully written and contained a statement that he wanted; but I may be mistaken about the time. It may be a year or two. I know that they were in my possession for a while, because [fol. 611] I received them and I studied them, and I know that he did not ask for them back right away.

100. Cross-question. When he did ask for them back, did he ask verbally or in writing?

Answer. To the best of my recollection, verbally. I feel very sure that he did not ask for them in writing; he was not so formal as that.

101. Cross-question. But you can not now tell whether you returned the original letters to Mr. Stone within a few months or a year or two after you received them?

Answer. I am trying to recollect. I would say that a considerable time had elapsed. My impression is that, or my recollection is that Stone asked me for those letters back again and that I gave them to him unquestionably, feeling that they were part of his records and feeling that he wanted them.

102. Cross-question. But you can not fix now any definite time when you did actually hand them back or send them back to Mr. Stone?

Answer. I can not recall. I will say this, that it might have been at the instance of his business associate that I returned them. I feel sure that when Stone wrote me those letters his only object was to get the matter on record, with the date and my acknowledgment, and he was acting as an individual at the time. I feel inclined the reason he asked me to return them was that he was asked to do so by his business associates. He regarded it as very important. That is my general impression.

103. Cross-question. Did you return the originals of these letters, defendant's Exhibits Nos. 2 and 3, to Mr. Stone prior to the time you made your affidavits in defendant's Exhibits 4 and 5?

Answer. I believe so.

104. Cross-question. I am not asking for your belief. I want to know whether you can swear that you returned them prior to the time you made either one or both of those affidavits?

Answer. I am not prepared to swear that I did. I think that I did. I am almost sure that I did.

105. Cross-question. After you returned the originals of these letters to Mr. Stone, of which defendant's Exhibits Nos. 2 and 3 purport to be copies, did you ever see them again?

Answer. Yes, I think I did. I think I saw them in his office. He had an office with his business associates, the Stone Wireless Telephone & Telegraph Co.

106. Cross-question. Just give me any definite time when you saw them after you returned them?

Answer. I think I saw them at the time I was requested to make one or more of these affidavits. I think I recollect that Stone showed me the letters and asked me if I remembered about them, asked me to look them over, and then they stated that they wanted me to make these affidavits. I think they refreshed my memory by handing me the letters.

107. Cross-question. You are positive of that, are you?

Answer. All but positive.

[fol. 612] Redirect examination.

By Mr. Scull:

108. Redirect question. You said in your cross-examination that professor Stone at the time that he was engaged by the A. T. & T. Co. or the American Bell Co. was engaged principally in business or matters relating to mathematics. What sort of mathematics? In general, what did such mathematics relate to?

Answer. One subject that he devoted a good deal of time to was the subject of the attenuation of telephone currents and the subject of distortion. At that time a great deal of experimental work was being done on telephone relays, and that was considered a very important subject, to discover the causes of attenuation and distortion.

109. Redirect question. Then, generally, these mathematics related to electric currents?

Answer. Yes, sir.

110. Redirect question. Was Professor Stone considered a mathematical expert in electricity at that time?

Answer. I considered him one. I do not believe he had a very wide reputation as one.

111. Redirect question. Several times in your cross-examination you used expressions such as "I think I recollect"; just what did you mean by that phrase?

Answer. I was trying to give the best impression I could dig up in my memory.

112. Redirect question. That is to say, you were trying to give your present recollection?

Answer. My present recollection, as I look back upon the circumstances.

* * * * * * *

John Stone Stone, a witness called on behalf of the defendant, being duly sworn, deposes and says in answer to interrogatories as follows:

Direct examination.

By Mr. Scull:

1. Question. Please give your present occupation and residence.

Answer. I am consulting electrical engineer, and residue at 34 Gramercy Park, New York City.

2. Question. Will you please state in general your experience with oscillation circuits, electrical radiation, electrical resonance, and wireless telegraphy and telephony prior to the year 1900?

* * * * * * *

Answer. I studied mathematics and physics at Columbia University, New York City, and Johns Hopkins University, Baltimore, Md., during the years from 1886 to 1889, inclu-[fol. 613] sive. During the latter two years of my studies at the Johns Hoqkins University the subject matter of electrical radiation was attracting a great deal of attention owing to the beautiful and sensational experiments of Professor Hertz. In consequence of the general scientific interest enhanced in radiation, so called, I studied the question of electrical oscillations and read considerable literature relating to both electrical oscillations and electrical radiation.

On leaving Johns Hopkins University in 1890 I entered the employ of the American Bell Telephone Co. as experimentalist in the laboratories of the company. There I continued the study of electrical oscillations and electromagnetic radiation and waves, and particularly the work then being done and published by Prof. Elihu Thompson and Nicola Tesla.

My attention was focused still further upon these subjects owing to the fact that in the spring of 1892 the chief engineer of the company, Mr. H. V. Hayes, asked me to investigate the possibilities of transmitting speech telephonically, without wires through the use of Hertzian waves, and, if possible, to devise means for thus producing what we now call radiotelephonic transmission.

During the year 1892, or a considerable part thereof, I prosecuted experiments with a view to accomplishing radio-telephony by Hertzian waves, using the Hertz oscillator in combination with a Tesla high-frequency coil apparatus.

These experiments led me to the conclusion that in the absence of a quantitative continuously active detector it was impracticable to transmit speech by Hertzian waves over any except commercially insignificant distances, and as a result of this conclusion my experimental work with high-frequency oscillations and telephonic transmission by electromagnetic waves was directed into a somewhat new channel, namely, into the development of what is now called "wired wireless." This wired wireless differs from the ordinary wireless or radio chiefly in the fact that the stations are connected by a conducting telegraph or telephone wire which serves to guide the waves from one station to another. In fact, the wired wireless to-day is merely a system comprising transmitters and receivers identical with the radio transmitters and receivers connected to a telegraph or telephone wire.

The object of all this work was to secure multiple transmission of messages over a single wire, and this was accomplished by impressing alternating or oscillating currents on the line at the transmitter and selectively receiving these currents in a resonant circuit attuned to the frequency of the incoming oscillations at the receiving station. Several transmitters each employing different frequencies or oscillations were used, and a corresponding number of resonantly tuned receiving circuits were used at the receiving stations, each receiver being attuned to the frequency of one of the transmitters.

I filed applications for patents for some of these inventions in wired wireless in 1893, and in 1894 I got into two interferences in the United States Patent Office involving the applications of Prof. I. Pupin, of New York City, and Messrs. Hutin and Le Blanc, two well-known electrical engineers of Paris, France. These interferences, or at all events, the interference with Professor Pupin, extended over a period of some eight years, and as a result of this interference my interest in the subject was kept alive even [fol. 614] after my experimental work ceased, and it became necessary for me to closely study everything that was published on the subject of electrical resonance and electrical oscillations and allied matter.

I also undertook a rather more comprehensive mathematical investigation of the subject of electrical resonance than had theretofore been made, and so also did Professor Pupin, whose mathematical work upon the subject of resonance in coupled circuits I had occasion to study in the course of this interference.

Early in 1899, in January or February of that year, I left the laboratory of the American Bell Telephone Co. and opened an office of my own in Boston, my only remaining connection with the American Bell Telephone Co. being that I was retained as advisory expert in connection with their patent litigation.

During the progress of my work with wired wireless in the laboratory of the American Bell Telephone Co., Prof. Charles R. Cross, of the Massachusetts Institute of Technology, became interested in my results and asked me to deliver a short course of lectures each year to the graduating classes in physics and electrical engineering at the Massachusetts Institute of Technology, and I delivered a course of lectures over a period of years from approximately 1896 to 1905 or 1906.

Shortly after I opened my office at the Phillips Building in Boston I was consulted by Herman W. Ladd, who had invented a system for determining the direction of the waves in radiotelegraphic communication, who wished me to look into the possibilities of his invention and give him such expert advice as I could in the matter.

A syndicate known as Ladd Wireless Telegraph Syndicate was formed, and early in the year 1901, as nearly as I can remember, I began experiments on the Ladd invention and continued them for some time.

In 1899, shortly after leaving the American Bell Telephone Co.'s laboratory, I conceived the idea of applying the principles which I had worked out in connection with my wired wireless experiments, to the elimination of what I have considered the principal practical obstacle to successful radiotelegraphy.

At that time, and even to-day, radiotelegraphy suffers very seriously from what is known as "interference." This interference is of two kinds, one kind being due to atmospherical electrical disturbances arising from natural as well as artificial causes, and the other kind is due to the reception of messages from other stations than those with which communication is desired.

The first kind of interference is usually referred to as static, and the second kind of interference is usually called station interference.

3. Question. I would call the witness's attention to the fact that the question was simply to state his general experience.

Answer. Yes; but I am not through. The avoidance of this interference I undertook to secure through the production of pure simple harmonic electromagnetic waves at the transmitter, which should be very much less damped than was common to radio waves in those days, and at the receiver through the use of very highly selective or very accurately resonantly attuned circuits loosely coupled to each other.

[fol. 615] 4. Question. Where was the laboratory of the American Bell Telephone Co. located; I do not mean the street; simply the city?

Answer. During the first year that I was with the American Bell Telephone Co. the laboratory was in Boston, and during the latter years it was in South Boston.

5. Question. Is there a system of wireless telegraphy known as the Stone system?

Answer. There is such a system.

6. Question. I will ask you to describe that system and give the history of its development.

Answer. Do you want me to recite about the patent application, etc.?

7. Question. The question is: Please describe the system and give the history of its development.

Answer. The Stone system, broadly speaking, comprises a transmitter, means for producing electromagnetic waves of a simple harmonic character, that is to say, of a single frequency and of high persistency, and at the receiving station of means for selectively receiving the energy of the incoming waves of one frequency to the practical exclusion of the energy of in coming waves of any other frequency.

Specifically the means employed at the transmitting station is a primary oscillating circuit, comprising a spark gap, a condenser, and the primary coil of an oscillation-transformer the secondary coil of which is included in the aerial circuit.

The primary oscillating circuit may or may not comprise an auxiliary inductance coil and the secondary circuit may also comprise an auxiliary inductance coil.

The generation of waves of but a single frequency, that is to say, simple harmonic waves, is effected in this system through the extremely loose coupling of the primary oscillating circuit with the secondary or aerial circuit.

The loose coupling between the primary oscillating circuit and the aerial circuit is effected either through making the mutual induction between the primary and secondary helixes of the oscillation transformer or Tesla coil small, per se, or through the addition of inductance to the primary and secondary circuits by means of the auxiliary inductance coils therein.

At the receiver, in its simplest form, the detector and indicating devices are associated with a local resonant secondary circuit comprising a condenser, and a secondary of an oscillation transformer, this circuit being resonantly attuned and very sharply attuned to the frequency of the waves, the energy of which is to be received therein.

The primary or open aerial circuit comprises the primary coil of the oscillation transformer.

The primary and secondary circuits are very loosely coupled with each other, and this looseness of coupling may be effected either by making the initial inductance in between the primary and secondary coils of the oscillation transformer small, per se, or by the addition of auxiliary self-induction to either of these circuits through the addition of auxiliary inductance coils.

In this specific system all four of the circuits described are very accurately attuned to the same frequency, said [fol. 616] frequency being the frequency of the electromagnetic waves used in transmission between the stations.

A modification of this specific system described above is sometimes resorted to when either greater selectivity than can be obtained by the simpler system is required.

This modification consists in the addition either at the transmitter or at the receiver, or both of a circuit which I have called a "weeding-out" circuit, or sifting circuit. This "weeding-out" or sifting circuit is a closed, highly resonant electric circuit, comprising a primary and a secondary coil of the transformer, and a condenser, and it may also comprise an auxiliary induction coil.

This "weeding-out" or sifting circuit, when used, is interposed between the aerial and the primary oscillating circuit at the transformer, and between the aerial and the resonant local receiving circuit at the receiver, and when it

is used it is inductively coupled very loosely both with the aerial and with the local resonant or oscillating circuit with which it is associated. It serves the purpose at the transmitter, so to speak, of weeding out any frequencies that may be developed in the primary oscillator other than that to which the primary oscillator and aerial are attuned, and it also serves the purpose of increasing the persistency of the waves developed at the transmitter, if properly constructed.

This circuit, containing as it does nothing but the coils and the condenser, is extremely selective of one frequency to the exclusion of all others, and its function is to bar the passage of any frequency but that one frequency to which it is attuned.

At the receiver the "weeding-out" circuit is inductively and very loosely coupled with the aerial on the one hand and with the "weeding-out" circuit on the other hand, and is attuned to the common frequency of the aerial and local resonant receiving circuit.

The Stone system comprises in addition to this apparatus a host of other radio-telegraphy devices and systems, such as systems for directing space telegraph signals and relay space telegraph signals, etc., covered by some 100 or more United States patents and a corresponding number of foreign patents; but I do not understand that you are interested in that phase of the system here. I have not answered your question fully.

8. Question. Permit me to ask here before you take up the development of the Stone invention: Am I correct in understanding that the transmitting and receiving devices which you have explained including some source of power and a key by which the power is controlled at the receiving station by some form of detecting device?

Answer. Yes; the usual form of power supply connected in the usual manner to the terminal of the spark gap at the transmitter and, similarly as I believe I mentioned in my answer, detectors and indicating devices associated with the receiving circuit in the usual manner.

9. Question. Now, will you please state the development of the system you have just described as the Stone system?

Answer. I conceived this system in the late spring or very early summer of 1899. I first disclosed and discussed the system to my friend, Mr. J. B. Baker, in the summer of 1899, and shortly afterwards to my patent attorney, Mr.

[fol 617] Alexander P. Brown, of Boston, the system I disclosed to these gentlemen being the system I have just described.

I do not at the moment exactly remember when I made these disclosures to Mr. Brown, but as near as I can remember it was in the fall of 1899; but I do remember the fact that it was in the summer of 1899 and in the early summer of 1899 that I disclosed the Stone system or the invention of the Stone system to Mr. A. P. Brown, then of Boston.

Mr. Brown prepared and filed applications for patents covering the specific system I have just described and also assisted me in securing capital for the exploitation of the invention, and I remember that I went with Mr. Brown to see his cousin, James Maynadier, in an effort to secure financial support from the Delbear Wireless Telegraph Syndicate, of which Mr. Maynadier was counsel.

Finally in 1901 Mr. Brown and I secured the necessary financial arrangements to enable us to form the Stone Wireless Telegraph Syndicate, which, as near as I can remember, was formed early in 1901 This syndicate supplied $10,000 for the purpose of testing the invention in a laboratory to such a point as to warrant the expenditure of considerably larger sums in the field experiments, it being agreed that if the laboratory tests showed that the invention was operative and secured the selectivity which we sought, the syndicate would organize a company and pay into the treasury of that company $10,000 in cash.

Through the year 1901 I conducted experiments with the Stone invention that I had disclosed to Mr. Baker, and which I had described in my patent application.

10. Question. What form did your disclosure of your invention to Mr. Baker take?

Answer. My disclosures to Mr. Baker were both oral and in writing, but I here refer to the invention I disclosed to Mr. Baker in writing, in two letters, dated June 30, 1899, and July 18, 1899, photolithographic copies of which I hand you.

Mr. Scull. Witness refers to defendant's Exhibits Nos. 2 and 3.

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11. Question. Did you testify in reference to the matters about which you have been questioned to-day in a suit in the eastern district of New York between the Marconi Wireless

Telegraph Co. of America, plaintiff, and the Atlantic Communication Co. and others, defendants, on Marconi patent No. 763772, some time during the year 1915?

Answer. Yes.

12. Question. At that time did you produce the originals of the letters, defendant's Exhibits Nos. 2 and 3?

Answer. I did.

13. Question. And do you know whether or not such originals were offered in evidence in that case?

Answer. They were.

14. Question. Did you also at that time produce photolithographic copies of the original letters which were offered in evidence?

Answer. Yes.

[fol. 618] 15. Question. Please examine defendant's Exhibits 2 and 3 and tell me whether or not those are duplicates of the photolithographic copies which you produced at the former trial?

Answer. They are.

16. Question. And so far as you can remember are these copies, defendant's Exhibits Nos. 2 and 3, exact reproductions of the original letters?

Answer. They are.

17. Question. Do you know who had these photographic copies made of the original letters, and if so, when was it done?

Answer. I looked that matter up at the time I testified in the other case, but I do not remember it now.

18. Question. Just your recollection.

Answer. I do not remember the date at which these photolithographic copies were made, but I do remember that they were made to be attached to an affidavit which Mr. Baker made in connection with the prosecution of one of my subsequent apllications for patent in the United States Patent Office.

19. Question. I show you a copy of a patent to John Stone Stone, numbered 714756, granted December 2, 1902, the application date of which is stated on this copy to be February 8, 1900, and ask you what that patent is, and whether or not it has any relation to the matters to which you have just testified?

Answer. This patent is the first patent which discloses the Stone system to which I have referred in my previous testimony, and discloses the Stone invention to which I have

referred in previous answers in this deposition. Do you not want me to go ahead and continue the answer which we interrupted for this purpose?

20. Question. Yes; please continue your answer to question 9.

Answer. As these experiments with the Stone system in the laboratory progressed I finally attained a degree of perfection in selectivity which was satisfactory to myself, it being what is sometimes called 10 per cent selectivity. I was not, however, satisfied to rely upon my own opinion in the matter, and so I called upon my friend, Prof. Charles R. Cross, who held the chair of physics at the Massachusetts Institute of Technology, to come and witness his experiments and express his opinion as to their success.

I also called upon my former professor of electricity and magnetism at the Johns Hopkins University, Dr. Louis Duncan, to express his opinion as to my results.

Both of these gentlemen reported highly favorably upon my work, and I therefore recommended that the work be carried into the field, and this was done as near as I can remember early in 1902. I then caused two small stations with a mast only 40 feet high to be set up on the Charles River embankment at Cambridge, across the river from Boston. These stations were very small affairs, and were only about a quarter of a mile apart. One of the stations was equipped as a transmitter and receiver, and the other station purely as a receiver. The transmitter employed was the Stone transmitter, as I have described it in answer to preceding questions, and as set forth in United States patent No. 714756. The receivers used were also Stone [fol. 619] loose-coupled receivers, which I have heretofore described in answer to your questions. Though in my patents and in some of my disclosures to Mr. Baker and Mr. Brown the conductive coupling of oscillating circuits at the transmitter with the aerial, and the conductive coupling of the local receiving circuit with the aerial at the receiver, were considered as alternative arrangements; nevertheless in all my experimental work and in all the apparatus that I actually built for commercial purposes the inductive coupling both at the transmitter and at the receiver was strictly adhered to.

The experiments between these two small stations were conducted as nearly as I can remember for a period of a few months only. Then the height of the mast at the trans-

mitter was increased very considerably, being somewhat over 180 feet, as I remember it, and the power of the transmitter was correspondingly increased, and with this increased power transmitter I was able to get reports from distant wireless stations of the performances of the transmitter, and I was also enabled with the increased antennae height to receive messages from more distant stations and judge of the power of the selectivity of my receiver to exclude extraneous signals.

I do not remember exactly at what period, but I think it was in the latter part of the year 1901 or early in 1903, I constructed a third station at Lynn, Mass., and continued experiments between Cambridge station and this Lynn station. During a period of nearly three years after the organization of the Stone Telegraph & Telephone Co. the company attempted to do no commercial business, but confined its efforts to developing experimentally a host of inventions related to the Stone system, as hereinbefore described in this deposition, and in conducting research work bearing upon the perfection of the apparatus of the Stone system. A hundred or more United States patents were applied for covering the results of this work.

Finally in the latter part of the year 1904 or the early part of the year 1905 the Stone company undertook to secure contracts from the United States Navy to supply its shore stations and ships with apparatus, and I recollect that the Navy Department agreed to permit the Stone company to equip its Portsmouth and Boston radio stations with its system, if it could establish direct communication between those two points, Portsmouth and Boston.

Prior to that time the Navy wireless stations at Portsmouth and Boston had been unable to communicate with each other directly, and were obliged to make use of a relay station for repetition of the messages at Hatchs Island.

Shortly after the Stone company equipped these two stations communication was established between them; the Government abandoned its Hatch Island station and accepted the Stone company's apparatus.

Shortly after this, or at about the same time this equipment was going on, the Stone company equipped the United States collier *Lebanon*, and later the United States battleships *Minnesota* and *Georgia*.

I can not remember the dates of those equipments, but the Stone company equipped a few battleships, some naval

stations, such as Pensacola, and some auxiliary vessels for the Navy, doing a net business that I should estimate without pretending to be very accurate, at $50,000.

[fol. 620] I should also roughly estimate that the money expended by the Stone company in developing its various inventions and patenting them was about $200,000.

I was chief engineer of the company from the date of its organization until it went out of business, I believe in the latter part of 1909. I think that about answers your question.

21 Question. Who was Mr. J. B. Baker, to whom you wrote the letters, defendant's Exhibits 2 and 3, and generally what were your relations with him?

Answer. Mr. Baker was an electrical engineer whom I first met in 1892 at the laboratory of the American Bell Telephone Co. where he was engaged in experimental work. Mr. Baker and I were associated in the work of the laboratory of the American Bell Telephone Co. until he left, I believe in the year 1896.

Thereafter I saw Mr. Baker from time to time as he remained in Boston. Mr. Baker afterwards entered into the employ of the Stone Telegraph & Telephone Co. as one of my assistants, and Mr. Baker was also at one time associated with me in the offices connected with the Ladd Wireless Telegraph Syndicate.

I do not remember the exact dates at which Mr. Baker was employed with me, but I know that he assisted me in my experiments at my laboratory at 40 Lincoln Street during the year 1901.

I also remember that Mr. Baker did some work for me in connection with my Cambridge station during the early periods of that work.

Furthermore, Mr. Baker at one time, though not in the regular employ of the Stone company, conducted some *research* at the Boston Public Library for me in connection with the literature of radiotelegraphy.

22. Question. In the summer of 1899 when the two letters, defendant's Exhibits Nos. 2 and 3, were written, were you and Mr. Baker associated in any way?

Answer. No. Mr. Baker and I were merely friends. He used to call upon me quite frequently at my office in the Phillips Buildings, and we would go to luncheon together, and he would call at my house, and I at his. This refers to the time in 1899.

23. Question. Did you disclose to Mr. Baker, other than in the letters, defendant's Exhibits Nos. 2 and 3, the inventions which you then had in mind, and if so when and how?

Answer. Yes; I disclosed inventions to him in the course of conversations at my office, and when we were at lunch together, and when we called upon each other at out respective houses. We discussed the inventions at some length.

24. Question. I show you defendant's Exhibit 1 and ask you if you recognize it?

Answer. I do.

25. Question. Will you please state briefly what you recall as to that exhibit, defendant's Exhibit 1?

Answer. I recall that the letter, of which this is a photolithographic copy, was a letter which I received from Mr. Baker in answer to the two letters I wrote him on June 30 and July 18, respectively, of which photolithographic copies are in evidence in this case.

26. Question. Defendant's Exhibits Nos. 2 and 3?

[fol. 621] Answer. Yes; defendant's Exhibits Nos 2 and 3 in this case.

27. Question. At or about the time of these letters, or shortly thereafter, did you disclose the invention set forth in these letters, defendant's Exhibits Nos. 2 and 3, to anyone other than Mr. Baker and Mr. Brown, whom you have mentioned?

Answer. Yes; I remember specifically disclosing the invention to Mr. James Maynadier and G. W. Pickard.

I have referred to the circumstance of this meeting in a previous answer. I can add here that at the interview in question Mr. Pickard was present as Mr. Maynadier's expert and I further remember that I disclosed the patent to Mr. Pickard both orally and by exhibiting to him a draft of my application for patent which finally resulted in patent No. 714756, or a copy of the application, I forget which.

I cannot place the date of this interview very accurately, bút it must have been prior to and in fact a considerable time prior to the formation of the Stone Wireless Telegraph Syndicate, as the object of the visit was to secure financial support for the *a*exploitation of the invention, and we made no further effort to secure financial support in that way after formation of the syndicate.

28. Question. You have stated that you gave lectures at the Massachusetts Institute of Technology. Did you refer

to your inventions set forth in defendant's Exhibits Nos. 2 and 3 in any of those lectures?

Answer. The title of my lectures was "Electrical oscillations and their applications." In my lectures I referred to all the applications I had personally made, as well as the applications others had made of electrical oscillations. After I had conceived the invention which I have referred to in this deposition as the Stone system, I made it a custom to describe it in these lectures.

29. Question. Had you applied for any patents prior to the summer of 1899?

Answer. Yes; I had applied for quite a large number of patents prior to that time, as near as I can remember some 20 patents relating to telegraph and telephone systems and to so-called "wired wireless" systems and to electrical resonance per se.

30. Question. Referring now to the various Stone stations which you have described, were there any distinctive characteristics common to all of them, and if so, please describe them?

Answer. Yes. The Stone stations were all equipped with the same type of apparatus, having the characteristics I have described as characteristic of the Stone system in my former answers in this deposition.

Perhaps the most unique characteristic of all these stations was the fact that waves developed at the transmitter were simple harmonic in character; that is to say, contained but a single wave length.

The second characteristic was that the coupling of the primary oscillating circuit with the antenna circuit at the transmitter station was always inductive and always loose.

Another characteristic was that at the receiver the local resonance circuit with which the detector and indicator were associated was rendered highly resonant to the frequency of the waves, the energy of which was to be received, and this circuit was loosely coupled indictively with the aerial circuit. [fol. 622] A further characteristic of all these stations was that the primary oscillating circuit and the aerial at the transmitter were attuned to the same frequency, or perhaps, as it may be more accurately stated, the primary oscillating circuit was attuned to the fundamental of the aerial or radiating circuit, while at the receiving station the local resonant receiving circuit was accurately attuned to

the fundamental of its associated aerial or antenna circuit.

When two such stations were in communication with each other, the four circuits of the two stations were each attuned to the frequency of the waves by means of which the transmission was being effected.

31. Question. What was the special advantage, if any, of this single-wave length which you obtained?

Answer. The special advantage of the simple harmonic wave or wave of a single frequency is that if there be waves of two frequencies, part of the energy of the transmitting station is in the waves of each wave length, and if the receiver be highly selective, as is desirable in order to avoid interference, then the receiver only receives the energy of the particular waves to the frequency of which it is attuned, and the energy of the waves from the transmitter which are of a different frequency is lost so far as its useful effect at the receiver is concerned.

Again, when the energy of the transmitter is divided between two or more wave lengths it is difficult to secure as persistent trains of waves as when all the energy is concentrated in waves of a single frequency or wave length.

Finally, if one is trying to operate a considerable number of radio stations within a given area without mutual interference, it is much easier to accomplish this if each transmitter radiates waves of one frequency characteristic of itself. That is to say, if there are 10 stations in the group and each station radiates waves of two or more wave lengths, there will be waves of 20 or more wave lengths radiated, and for a given receiving station to exclude all but the waves from the particular station with which it desires to communicate it becomes necessary to employ wave lengths covering an enormous range of frequencies at the transmitters.

32. Question. You have stated that in your system the four circuits of the system were attuned. Please state what specific means of tuning were used at your various stations?

Answer. The most common means we employed in tuning the primary oscillator of the transmitter to the fundamental of the antenna was a spark gap placed across the secondary coil of the transformer.

The primary oscillating circuit was adjusted until a maximum spark could be drawn across the secondary coil in the antenna circuit, this indicating a maximum resonant rise of potential in the antenna circuit and indicating with a very

high degree of precision, under the conditions which we worked the exact attunement of the primary to the secondary.

Later, when wave meters became more common and when hot wire ammeters were more plentiful, these two means were also used by my assistants, but in all my earlier work the spark gap was used at the transmitter in the way in which I have described it.

At the receiver the attunement was usually made by varying the adjustment until a maximum certainty of response [fol. 623] was secured; and I refer to response of the detector and indicator, though in my early experiments at the laboratory at 40 Lincoln Street I not infrequently attuned the local receiver circuit by the spark method, taking it across the room to the transmitter and directly observing the resonant rises of potential at the condenser, when the period of the local circuit was the same as that of the transmitter.

In those experiments the antenna at the receiver was always made identical with the antenna at the transmitter, so that they were necessarily in tune.

33. Question. In making these adjustments in the receiving circuit, what features or parts of the circuit were changed to give the desired variation?

Answer. In the early experiments of the transmitter I varied the capacity of the large air dielectric condenser which I employed in the primary oscillating circuit, while in the later commercial apparatus the inductance of the primary circuit was the element that was varied for the purposes of tuning.

At the receiving station in the early experiments the tuning was almost accomplished by variations of the capacity of the receiving condensers in the local receiving circuit, though in that of later commercial apparatus large variations in tuning were made by cutting in and out additional amounts of inductance, and the intermediate variations of freqency were made by continued variations of the local condenser.

The tuning of the antenna, both at the receiver and the transmitter, in the early experiments, was invariably made by varying the number of turns of the helix of the oscillation transformer in that circuit, both at the transformer and the receiver, and this particularly persisted in the commercial apparatus, except that in the commercial apparatus

a condenser was sometimes included in the aerial circuit, and this was varied in the process of tuning, but the condenser used in the aerial circuit of these commercial receivers was not placed there for the purpose of tuning, but for the purpose of a subsequent invention which enabled us to give the aerial circuit an opportunity to respond to atmospheric disturbances at a frequency which would not disturb the local receiving circuit.

In other words, we gave the verticle system two natural frequencies and attuned the local receiving circuit to one of them.

34. Question. What was the result of this tuning, first with regard to the two circuits of the transmitter, then with regard to the two circuits of the receiver, and finally to all four circuits together?

Answer. The result was that two stations so adjusted were very accurately attuned to each other, and that each of the four circuits were attuned very accurately to the same frequency.

* * * * * * *

35. Question. In some of your previous answers you have referred to the fundamental of the aerial circuit. Will you please explain what you mean by that expression?

Answer. The aerial circuit or antenna has a number of natural periods to which it will respond and the lowest or gravest natural mode of vibration of the aerial is called its [fol. 624] fundamental, while the higher or more rapid natural modes of vibrations are usually referred to as harmonics, though they are not always strictly in a harmonic ratio to the fundamental.

To be a little more elementary and specific in my description of this term, as I have used it in this deposition, I will say that if you impress a vibratory or alternating electric force upon an aerial system and slowly vary the rate of vibration of the force, the aerial will practically not respond to the force; that is to say, will have negligible oscillations developed in it, except when the period of the force is the same as the natural period or fundamental of the aerial. Then, as the frequency of the force is still further raised, the aerial will again cease to respond or practically cease to respond to the force, until the period of the force equals the period of the first harmonic natural

rate of aerial, when again the aerial will respond with considerable energy.

As the period is still further increased, again the aerial will practically cease to respond to the force until the period of the force equals the second harmonic natural period of the vertical, and so on.

If the aerial conductor be excited into what is called natural oscillations, simply charging it with electricity and allowing it to discharge to earth, it will vibrate with the period of oscillation corresponding to the fundamental, and also with vibrations corresponding to each one of the harmonics; but if the aerial be excited by a simple harmonic force it will vibrate with the rate of vibration equal to that of the force, and whether or not it responds appreciably will depend upon whether the period of the force corresponds to the fundamental or to one of the harmonics.

If the period of force does not correspond to the fundamental of one of the harmonics of the aerial practically no oscillations will take place in the aerial.

36. Question. When an antenna circuit is vibrating, both in the fundamentals and in the harmonics as you have stated in this last answer, what is the resultant effect so far as the waves radiated are concerned?

• • • • • • •

Answer. Waves are radiated which have frequencies corresponding to the fundamental and all the harmonics.

37. Question. In your description of the Stone system you have repeatedly stated that the primary and secondary circuits were loosely coupled. Why did you use this "loose coupling"?

Answer. The loose coupling was used to secure a simple harmonic oscillation of the aerial and a corresponding simple harmonic radiation; that is to say, radiation of waves of a single wave length.

According to the theory of coupled oscillators it is possible to secure oscillations of a single frequency with two coupled oscillators only, when the coupling is either extremely tight or extremely loose.

In the case of an extremely tight coupling the two oscillators so coupled must be attuned to extremely different periods, while in the case of an extremely loose coupling the oscillators must be attuned to the same natural period, in order that a simple harmonic oscillation may result.

That is the reason I adopted the extremely loose coupling in my system, in order that I might get waves having but a single frequency.

[fol. 625] 38. Question. Have you any photographs or other contemporary records illustrating the various installations of the Stone system which you have previously referred to?

• • • • • • •

Answer. I have certain photographs of some of the stations in question and of the apparatus contained in them, but I have them not in my possession at present, as they were introduced in evidence by the defendant in the suit of the Marconi Co. against the Atlantic Communication Co., which has been previously referred to.

39. Question. Were the photographs which you there produced offered in evidence in that case?

Answer. Yes.

40. Question. Have you any present recollection of what those photographs were and what they showed?

• • • • • • •

Mr. Scull: Defendant's counsel states now, as he did in reference to previous copies offered in evidence, that the originals are part of the records in the Atlantic Communication Co.'s case and are not available for use in this case.

• • • • • • •

Answer. I described in my testimony in the Atlantic Communication Co.'s case what these photographs showed. Without having them before me I do not suppose I could describe them here so well.

41. Question. I note that at page 570 of the record in the Atlantic Communication Co.'s case, you produced and described a sheet of photographs which you then stated showed experimental stations on the Charles River embankment at Cambridge. With this to refresh your recollection can you describe now what that photograph showed?

Answer. I can if I refer to the testimony I gave in the Atlantic Communication Co.'s case to refresh my memory.

42. Question. I hand you a copy of the record in the Atlantic Communication Co.'s case and refer you particularly to pages 570 to 573, in which certain photographs are referred to, and with that testimony before you, I ask you

to briefly state what the photographs were that you then produced?

• • • • • • •

Answer 7. The first photograph or sheet of photographs referred to showed the experimental stations on the Charles River embankment to which I referred in this deposition, and showed the transmitting station after the 180-mast had been set up. On the reverse side of the sheet the photograph showed the interior of the transmitting station, and particularly showed the very large air condensers used in [fol. 626] the oscillating circuit of the transmitter and also the oscillation transformer, indicating the fact that these were open wire coils spaced some little distance apart, indicative of loose coupling.

The second photograph was a photograph of the interior of the Portsmouth Navy Yard station which bore a date "September, 1905." On the back of this sheet there were some photographs of stations other than the Stone stations.

The next photograph was one of the Stone Lynn, Mass., stations, which is dated "1903-04."

The next photograph showed the Stone station at the Isle of Shoals and is dated "September, 1905."

The next photograph shows the Stone apparatus, equipment on the U. S. S. *Lebanon* and is dated "September, 1905."

The next is sheet of photographs illustrating the navy yard station at Charlestown, Mass., after the Stone equipment was put in. It shows specifically the 3-kilowatt power plant, as well as the 3-kilowatt transmitting apparatus.

Another sheet of photographs here shows the Stone transmitter and receiver coils at the Charlestown Navy Yard, and from the character of these coils it is evident that the apparatus is of the loose-coupled type.

Another sheet of photographs shows the radio station on board the U. S. S. *Lebanon* and one of the photographs is interesting as showing the use of three-tune circuits at the receiver, one of these circuits being the "weeding-out" circuit to which I have referred in this testimony.

Another sheet of photographs shows the Stone receiving apparatus at the Charlestown Navy Yard, dated October and November, 1905. This photograph also shows what I recognize as the three-tune circuit, indicating that here also the "weeding-out" circuit was used in the receiver.

A still further photograph shows particularly well the enormous air condenser which is used at the transmitting station at Cambridge, Mass., and also shows the oscillating circuit of the transmitter, the large sized wire indicating the primary oscillator coil, the fine wire coil being the secondary.

There is still another photograph showing the same elements.

Another photograph shows an operator using the apparatus at Charlestown Navy Yard, and the photograph shows that the weeding-out circuit was used in the receiver.

Another photograph which I offered in evidence in that case was one showing the air condensers and coils used in tuning the receiver at Lynn station.

* * * * * * *

43. Question. At the time these photographs were shown, when you testified in the Atlantic Communication Co.'s [fol. 627] case, did you recognize the apparatus and installations shown in them to be substantially what you have testified to?

* * * * * * *

Answer. I did.

44. Question. I note from the record in the Atlantic Communication Co.'s case that when you testified you produced an old slip of paper entitled "Notes for Mr. Baker, dictated by Mr. J. S. Stone." Have you a copy of that paper?

* * * * * * *

Answer. No; I have not that paper.

45. Question. Was that old slip of paper offered in evidence in the Atlantic Communication Co.'s case?

Answer. Yes.

46. Question. I find that when you testified in the Atlantic Communication Co.'s case you produced a letter which you described as being a letter addressed to you by Mr. Alexander Porter Brown, from Nantucket, Mass., August 14, 1900, relating to the communications which led up to the formation of the Stone Wireless Syndicate. Did you produce such a letter in this case?

* * * * * * *

Plaintiff's counsel calls attention to the fact that Mr. Philip Farnsworth, now counsel for the present defendant,

was also of counsel for the defendant in the Atlantic Communication Co.'s case.

Mr. Scull: Defendant's counsel calls attention to the fact that the paper here inquired about, as well as all the previous papers and documents which have been referred to in this deposition, are part of the court record in the Atlantic Communication Co.'s case, and not available to this defendant for the purposes of testimony in this case.

Answer. Yes.

47. Question. Have you a copy of that letter?

* * * * * * *

Answer. No.

48. Question. Were you or the Stone Co. or any of the companies referred to by you, with whom you have been connected, ever notified by the plaintiff, the Marconi Wireless Telegraph Co. of America, or any owners of the Lodge and Marconi patents here in suit, Nos. 609154 and 763772, of infringement by you or any of those companies, of either of those patents.

* * * * * * *

Answer. I certainly was not. I never heard of the Stone Co. or of any other company with which I might have been connected, being so notified, and I am quite sure that had the Stone Co. been notified I should have heard of it.

49. Question. For how long a period were wireless telegraph sets made according to the Stone system, which you have described, operated by you or by your company?

* * * * * * *

Answer. The Stone Co. was not an operating company. It manufactured sets for commercial purposes for the United States Navy, between early in 1905, until sometime [fol. 628] in 1909, when it shut down its business entirely.

50. Question. In the art of wireless telegraphy what is meant by the term "quenched gap"?

* * * * * * *

Answer. A quenched gap is a spark gap devised, specially designed to rapidly damp out the oscillations in any circuit in which it is included by cooling the spark.

The specific structure consists of a number of conducting plates of considerable mass, placed with their opposing surfaces in close juxtaposition, and with their edges so ar-

ranged so as to facilitate the radiation and conduction of heat away from the spark-gap device, and the connections of this series of plates is such that when used as a spark gap the spark has to jump across a succession of gaps between the plates, each one being very short, and immediate proximity of a large mass of metal.

51. Question. In the art of wireless telegraphy what is ment by the term "logarithmic decrement?"

• • • • • • •

Answer. In the old theory of the oscillations which place in an electric circuit when a condenser is charged with electricity, and then permitted to discharge through a coil and spark gap, the resulting electric oscillations begin with a maximum initial amplitude, and then decay according to what is called an expotential or logarithmic law, so that the ratio of the amplitude of each oscillation to the next preceding oscillation bears a constant value throughout the train of decrescent oscillations.

That is to say, if the second oscillation is nine-tenths as great as the first oscillation, then the third oscillation will be nine-tenths as great as the second oscillation, the fourth oscillation would be nine-tenths as great as the third oscillation, and so on throughout the train of oscillations.

According to this theory the oscillations practically never cease in a circuit, but simply continue to become smaller and smaller.

The function known as the decrement or logarithmic decrement of the oscillations or of the circuit is the natural logarythm of the ratio of the successive amplitudes which I have just described.

This theory was first advanced by Prof. William Thomson, afterwards Lord Kelvin, in 1853, and has been pretty generally made use of in all work relating to electrical oscillations, but it is not strictly applicable to any circuit containing the spark gap, and when the damping due to the spark gap is large compared to that due to the conductoral resistance it is not strictly applicable at all.

52. Question. I show you an article entitled "The resistance of the spark and its effect on the oscillations of electric oscillators," by John Stone Stone in the proceed-[fol. 629] ings of the Institute of Radio Engineers, under date of December, 1914, and ask you whether you are the John Stone Stone who is the author of that paper?

• • • • • • •

Answer. I am.

Mr. Scull. I offer the paper referred to in evidence and ask that pages 307 to 327 therein be marked "Defendant's Exhibit 6."

(Marked "Defendant's Exhibit 6.")

Mr. Betts. Objected to as immaterial; same objection.

53. Question. In an oscillatory circuit containing a quenched gap, a relatively large capacity, a relatively small conductance, and a relatively small conductor resistance, what kind of a decrement would there be?

*   *   *   *   *   *   *

Answer. There would be what is known as a linear decrement, in contradistinction to a logarithmic decrement the linear decrement being the kind of decrement discussed in my paper before the Institute of Radio Engineers, defendant's Exhibit 6, illustrated in Figure 6 thereof, while the logarithmic decrement is the kind of decrement illustrated in Figure 1 of that paper.

In the case of the linear decrement there is no constant ratio between the amplitude or magnitude of the successive oscillations in an oscillation train, and there is therefore no logarithmic decrement or decrement in the sense that there is one in the logarithmic decrement theory.

54. Question. In describing the logarithmic decrement I believe you said that according to this theory the oscillations continue indefinitely. Is this true of an oscillation decaying according to the linear decrement?

*   *   *   *   *   *   *

Answer. It is true that according to the logarithmic decrement theory the oscillations are supposed to continue indefinitely, while in actual fact the oscillations die out, and the spark quenches after a definite time. The linear decrement theory shows definitely the extinction of the oscillations after a definite period of time.

55. Question. In an oscillatory system, having a primary circuit and a secondary circuit inductively connected, with a 10 per cent coupling, and a quenched gap in the primary, the circuits being adapted to quench the spark at the first beat, what is the maximum number of oscillations that could occur occur in the primary circuit?

*   *   *   *   *   *   *

Answer. Five and five-tenths, though in practice the spark would be more likely to quench and the oscillations cease after five complete oscillations have taken taken place.

56. Question. In your paper, defendant's Exhibit 6, there occurs the following language on page 313:

"While the question of the end of the train of oscillations is of only minor importance, since by the time the amplitude of the oscillations has reached one-fifth its initial value, [fol. 630] the energy of the remaining oscillations represents only four per cent of the total energy of the train."

What is the basis of your selection of one one-fifth of the total value of the amplitude of the oscillations for your calculation of the remaining energy in the wave train?

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Answer. My reason is primarily that stated in the paragraph you have quoted, because "the energy of the remaining oscillations represents only 4 per cent of the total energy of the train."

Now, the energy of the oscillations is the property of the oscillations which maintains the conductivity of the spark across the spark gap.

When the energy of the oscillations becomes too small to keep the gases incandescence at the spark gap, the spark quenches and the circuit opens.

It is therefore necessary, in considering when the spark gap will open through the quenching of the spark, to consider the energy of the oscillations rather than the amplitude of the current of the oscillations.

In most practical cases I should expect the spark to quench when the energy of the oscillation reached 4 per cent of the initial energy required to break down the spark gap; that is to say, 4 per cent of the total energy of the train.

57. Question. How much of the total energy of the train remains when the current has reached 1 per cent of the initial amplitude?

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Answer. One ten-thousandths part of the initial energy, or of the energy of the wave train.

Cross-examination.

By Mr. Betts:

Cross-question. I believe you stated on your direct ...ation that you applied for and were granted 100 or ... United States patents for your improvements in wire... legraphy, but that you only described one invention ... direct examination, and that was the matter which ...ant was interested in here. Am I correct?

...wer. I did refer to one other invention specifically; ..., the use of a condenser in the aerial circuit, which ...ployed by me to give the aerial circuit two natural ...cies, one of which absorbed largely the energy of ...nterference waves, and the other of which was util... the reception of messages, this invention being the ...of avoiding excessive disturbance from atmospheric ...ity. I do not remember in this deposition of de...g any of the other inventions.

...ross-question. What do you understand to be the ...volved in this case?

...er. I understand the suit is one brought by the ...i Co. under the Marconi so-called four-tuned circuit ... for infringement of that patent, or certain claims ...

...ross-question. And your deposition with respect to ...leged disclosures to Baker, Maynadier, Brown, ..., and the filing of your application for your patent ... No. 714756 is, as you understand it, for the pur... showing prior invention and use by you of the ... patent in suit.

...r. I conceive that that is the defendant's purpose ...g me.

...oss-question. And that is why you limited your ...xamination to describing in detail this invention, ...e possibility of such description as you have made ...ect to the other invention, which, as I understand ...s in the employment of a condenser in the aerial ... get two frequencies in that circuit; is that right?

...r. I simply answered the questions that were asked ... best of my ability. I did not see that any of the ... were directed toward any other of my inventions ... one that I described.

62. Cross-question. In what way, if at all, are you connected with the De Forest Radio Telephone & Telegraph Co.?

Answer. I am a stockholder in that company, having received a certain stock consideration in it when the bondholders of the Stone Co., of which I was one, sold some hundred of the Stone Co.'s patents to the De Forest Radio Telephone & Telegraph Co.; and, further, the De Forest Radio Telephone & Telegraph Co. made a contract with me that I should advise Doctor De Forest with respect to the possibilities of his constructing radio telephone or telegraph apparatus which should not infringe or fall within the scope of the claims of other radio telephone patents than those owned by the De Forest Co. That contract I believe has been abrogated through noncompliance on the part of the De Forest Co. with the terms of the contract. These two particulars are the only particulars in which I am in any way connected with the De Forest Radio Telephone & Telegraph Co.

63. Cross-question. And one of the patents which you were to advise the De Forest Co. on was this Marconi patent in suit No. 763772?

Answer. I was not called on to advise Doctor De Forest or the De Forest Radio Telephone & Telegraph Co. on the patent in question or any other patents. My function was purely to advise with Doctor De Forest with regard to the construction of radio transmitters and receivers which should not fall within the scope of the claims of certain patents, as they had been construed by the courts.

In other words, my function was purely that of an electrical engineer and inventor, and I was not called upon to construe the claims of the various patents which might be involved.

To make the matter clear I did advise Doctor De Forest on two circuit arrangements, one for a transmitter and the other for a receiver, some year and a half or two years ago, and since then have not had any further communication with him or the company.

64. Cross-question. Was not Marconi patent in suit No. 763772 one of the patents which you were called upon to advise the De Forest Co. on?

Answer. Yes, in the sense that I was called upon to devise apparatus which should not fall within the scope of the

claims of that patent as those claims had been construed by the several courts that had passed upon the patent in question; but I was not called upon to advise them as to the scope or validity of that patent.

[fol. 632] 65. Cross-question. One of the subject matters of this Marconi patent No. 763772 is the matter of attuning or tuning together the two transmitter circuits?

Answer. That is part of the subject matter of that patent.

66. Cross-question. And another part or subject matter of the Marconi patent No. 763772 is the matter of the tuning together of the two circuits of the receiver?

Answer. That is also a part.

67. Cross-question. And a third matter of this patent No. 763772 was the matter of tuning all four circuits together?

Answer. As I remember it, that is also a part of the subject matter of the patent, though I have not looked it up recently. It may be either that my recollection comes more from something that was said in one of the court's decisions than from what was said in the patent. I had not looked at that patent for some little time, and I might be likely to confuse some of the statements made by different courts that have considered it, with statements made in the patent specification itself.

68. Cross-question. When was it that you were called upon and did advise the De Forest Co. with respect to devising an apparatus which would not infringe or be within the scope of the claims of Marconi patent No. 763772, as construed by the Courts?

Answer. I do not remember the date. I could fix the date approximately if I knew the date upon which Judge Hough granted a preliminary injunction against the De Forest Radio Telegraph & Telephone Co. under the Marconi patent in suit.

69. Cross-question. Was it before or after that decision of Judge Hough?

Answer. It was before.

70. Cross-question. How many years ago was it?

Answer. I don't remember, but I should say that it was a year or perhaps two years ago.

71. Cross-question. How do you account for the fact that you can not remember that date when you pretend to remember the date of a disclosure to Baker more than 16 years ago?

Answer. In the first place, because the matter of the disclosure to Baker was a matter which was of very much greater importance to me, and in the second place, I had looked up and refreshed my memory upon the subject of all those early dates to which I have testified in giving depositions in several suits, and I have even before me the photolithographic copies of the letters that I wrote Baker at the time, copies of letters which I have had in my possession or which have been in the possession of my attorney ever since they were made years ago.

72. Cross-question. Did you advise the De Forest Co. or Doctor De Forest that the apparatus of the De Forest Co. which was the subject matter of the suit before Judge Hough was or was not within the scope of the claims of the Marconi patent as it had been construed by the court?

* * * * * * *

Answer. I advised Doctor De Forest that in my opinion the apparatus I recommended to him, and which he used in part, was not within the scope of the claims of the patent as those claims had been construed by the courts, which had passed upon them up to that time.

[fol. 633] 73. Cross-question. You are aware of the fact, are you not, that the Marconi Co. brought a suit against the De Forest Co., of which you are a stockholder, upon Marconi patent No. 763772 in suit?

Answer. Yes.

74. Cross-question. How many times have you testified as an expert in wireless telegraph cases?

Answer. I do not remember. I have testified quite a few times both as an expert and as principal in patent suits and in interferences in the United States Patent Office.

I have testified as an expert for the old defunct De Forest Radio Telephone Co. in a suit brought by that company against the Collins Wireless Telephone Co. and as expert for that old De Forest Co. in suits brought against it by the National Electric Signaling Co.

I have testified as an expert for the Telefunken Co. in suits brought against it by the National Electric Signaling Co.

I have also testified for the Atlantic Communication Co. in suits brought against it by the National Electrict Signaling Co., and as a fact witness in a suit brought against it by the Marconi Co.

I have testified as expert for Professor Fessenden in an action brought by him against the National Electric Signaling Co., and I have given affidavits for the present De Forest Radio Telephone & Telegraph Co. in a suit brought against it by the Marconi Co. under the patent in suit. I possibly also have given testimony in some other radio cases which I do not remember just now.

75. Cross-question. When you testified for the defendant Telefunken Wireless Telegraph Co. in the suit brought against it by the National Electric Signaling Co., and also for the defendant Atlantic Communication Co. in the suit brought against it by the National Electric Signaling Co., you remember the subject matter of plaintiff's patents involved in those suits was the tuning of the two circuits of the transmitter and the two circuits of the receiver?

Answer. I remember that the tuning of these circuits was involved, with regard to the transmitter I believe in one suit, and with regard to the receiver I believe in another suit. I do not remember that tuning all four circuits was involved in either one of these two suits; at least that is my impression now.

76. Cross-question. Did you in testifying in either one of those two cases for the defendents testify to the conception and the disclosure and exploitation of the Stone system which you have testified to on direct examination to-day in this suit?

Answer. No.

77. Cross-question. And yet that testimony that you have given to-day was applicable as a defense to both of the patents upon which these suits are brought.

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Answer. Undoubtedly. Unfortunately I was not asking the questions which I was called upon to answer in both those cases. The questions directed to me, as I remember the case, were not such as to bring out my prior conception, invention, and use of four-time circuits. I could only conclude that the defendant's counsel did not care in those suits to bring out my prior invention, disclosure and use of the four-tune circuits.

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[fol. 634] 78. Cross-question. Who were the defendant's counsel in these two cases?

Answer. Mr. Fenton, of Philadelphia, was the counsel in both of these cases, or the principal counsel in both of these cases.

79. Cross-question. Were not Knight Bros. of counsel for the Atlantic Communication?

Answer. If they were of counsel in either of those cases I did not come in contact with them in connection with either of those cases.

80. Cross-question. Did you tell Mr. Fenton when consulting with him about the defense of these suits, of your alleged prior conception, disclosure?

Answer. I certainly pointed out to Mr. Fenton the disclosures of my early patent No. 714756 and told him that I could produce evidence of early disclosure and use.

81. Cross-question. Did you produce that evidence to Mr. Fenton?

Answer. No; at least I do not remember producing it. In fact, I do not remember producing any evidence to Mr. Fenton except what he called for. There was very little preparation made for either of these suits between Mr. Fenton and myself. A very short time was allowed for conference before I went on the stand. To the best of my recollection Mr. Fenton and I conferred for only one day in New York City before I proceeded to Philadelphia and testified in the first suit, and in the second suit, though we had a somewhat long conference, it still was very short, considering the importance of the suit and the mass of evidence we had to discuss together.

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82. Cross-question. Were you aware of the litigation brought by the National Electric Signaling Co. against the United States Wireless Telegraph Co. in the courts of the first circuit at the time it was pending?

Answer. I think I heard about that litigation, but I did not know anything about it, except now that I think of it I remember that Mr. Farnsworth I believe represented or was of counsel for the United Wireless Co., and the expert which he called was, I believe, Mr. Waterman. I remember Mr. Farnsworth asking me to come to his office and to describe to him and Mr. Waterman, his expert, certain features of the Stone patent No. 714756 and to more or less analyze the patent for him.

83. Cross-question. The subject matter of plaintiff's patent involved in that litigation was the tuning together of

transmitter and receiver circuits, was it not, as you understood it?

Answer. It was.

84. Cross-question. And did you at that time disclose to Mr. Farnsworth the evidence which you have testified to to-day in regard to your alleged early conception and disclosure?

Answer. That question was not asked me, but I believe I did mention the fact that I could produce proofs of some very early dates of disclosure. The purpose of his inquiries was——

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[fol. 635] His inquiries were not directed toward the dates of my disclosures to others, but toward the interpretation which I had placed upon the language of the patent application itself.

* * * * * * *

85. Cross-question. In what month did you leave the employ of the American Telephone Co.?

Answer. I do not remember exactly what month. I think it was January or February of 1899.

86. Cross-question. How old were you in 1899?

Answer. I was about 30.

87. Cross-question. Your experiments in wireless telephony while you were connected with the Bell Co. were successful, were they?

Answer. No; except for the transmission of speech between rooms in the same laboratory, and even then the transmission was not loud.

88. Cross-question. How long did these experiments last?

Answer. I do not remember with any great precision how long the experiments on the purely radio line telephone lasted. I should say perhaps three months, before I became convinced that it was best to change to the wired wireless line.

89. Cross-question. Has anybody else except yourself ever used *used* the expression "wired wireless" line?

Answer. Yes; others have used it. In fact, I did not originate the expression. The only way I ever heard of it was when I wrote a paper for the Franklin Institute on a subject which I entitled "Practical aspects of the propagation of high-frequency currents in long wires," which the

Franklin Institute committee, in conferring a medal upon me for this paper, referred to as my paper on "wired wireless." I have since then adopted the shorter and more suggestive name of "wired wireless" for the art.

90. Cross-question. Well, it is popularly known as wired telegraphy or wired telephony?

Answer. No; it is popularly known as wired wireless, being distinguished in that way from the ordinary wired telegraphy and wired telephony, in which high-frequency currents, electrical oscillations, and resonance are not made use of.

91. Cross-question. In your direct examination you have used the expression "Resonant circuit." What do you mean by that expression?

Answer. The resonant circuit as I have used the expression in my patents and in this deposition is one comprising a capacity and an inductance in concentrated form, such as is obtained by the use of a condenser and an inductance coil; and so otherwise constituted that it shall have a very pronounced tendency to respond to alternating electric forces of one periodicity or frequency only. Such circuits are often spoken of as containing "lumped capacity" and "lumped inductance" in contradistinction to circuits like the open circuit of an aerial in radiotelegraphy, which has distributed capacity and distributed inductance along its whole length, though, of course, a circuit of the latter kind can, through the presence of a large inductance coil, be made to approach as nearly as desired to a pure resonance circuit.

[fol. 636] Moreover, when I speak of a resonance circuit, either in my patents or in this testimony, I imply that magnetic and dielectric hysteresis shall not be present to such an extent as to greatly militate against the resonant response of the circuit to the particular frequency to which it is tuned.

For instance, the iron core of a coil, such as the iron core in the coil of a telephone receiver, if allowed to intervene in a resonance circuit, would greatly if not completely kill the resonance phenomenon in the circuit; so such elements are assumed to be excluded when I speak of resonance circuits.

92. Cross-question. Do you or do you not use the term resonance circuit as synonymous with "oscillatory circuit"?

Answer. No. There is a nice distinction between those two classes of circuits, though, of course, an oscillating circuit when closed is necessarily a resonance circuit; but a resonance circuit is not necessarily an oscillating circuit.

Every circuit containing a lumped inductance and capacity will have a particular frequency to which it will respond, and respond fairly strongly, but only circuits having resistance less than the critical value will oscillate when their electrical equilibrium is distributed, and as I understand we now have my patent No. 714756 in evidence, and I would refer you to the definitions contained therein for the use of these two terms which I make.

The oscillating circuit I have called sonorous circuits, to distinguish them from resonance circuits.

93. Cross-question. Do I understand you to say that a closed circuit, comprising the helix of a transformer and capacity, must have additional or auxiliary lumped inductance in order to be a resonant circuit?

Answer. Not necessarily. As a rule, if the transformer contains no iron and the resistance on the circuit be not enormously high, and if the dielectric of the condenser be of suitable material, such a circuit may be very strongly resonant without any auxiliary inductance; but if it lacks resonant properties through the presence of considerable resistance, it might be made resonant by the addition of an auxiliary inductance coil.

94. Cross-question. Who was the successful party in the interference between Pupin, Stone, Hutin, and Le Blanc?

Answer. There were two interferences, one between myself and Hutin and Le Blanc, and one between myself, Professor Pupin, and Hutin and Le Blanc. I do not remember the outcome of the Hutin and Le Blanc-Stone interference, but I do remember that Professor Pupin prevailed in the three-party interference.

95. Cross-question. How did you fix the date when you left the Bell Co. in 1899?

Answer. I do not remember now exactly how I did fix that date, except that I had occasion to look up the lease of my office at the Phillip Building, the office which I took immediately after leaving the Bell Telephone Co. laboratory, and I fixed the date in that way, and by looking up everything I could find in that connection when I have testified on previous occasions in regard to my history.

96. Cross-question. When first did you begin to deliver the course of lectures at the Massachusetts Institute of Technology?

[fol. 637] Answer. I do not remember that date exactly, but I think it was 1896. It was about that time that Professor Cross, of the Institute of Technology, and Professor Trowbridge, of Harvard College, became interested in the work I was doing on electrical resonance, and I believe it was in that year that Professor Cross asked me to begin giving my course at the institute and Professor Trowbridge submitted my name for fellowship in the American Academy of Arts and Sciences.

97. Cross-question. Have you any memorandum which enables you to fix the date when you began to deliver your course of lectures at the Massachusetts Institute of Technology?

Answer. No; I do not believe I have any memorandum by which I can fix that date. Very likely Professor Cross could fix the date.

98. Cross-question. How long did you continue to deliver that course of lectures at the Massachusetts Institute of Technology?

Answer. I remember that I delivered the lectures at the Institute of Technology for some time prior to my leaving the laboratory of the American Bell Telephone Co., and for some years subsequent to that date. I think I stopped giving my lectures at the Institute of Technology about 1906.

99. Cross-question. Is that the most definite answer you can give?

Answer. Yes. I fancy that Dr. Louis Duncan, who was in charge of the electrical engineering course at Massachusetts Institute of Technology, about that period, could fix the date more exactly.

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100. Cross-question. Have you any memorandum which will enable you to fix exactly the date when you ceased to give your lectures at the Massachusetts Institute of Technology?

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Answer. I do not think that I have any memorandum by which I can fix that date.

101. Cross-question. Give the exact date when you were first consulted by Mr. Ladd?

Answer. I do not remember that date.

102. Cross-question. Give the exact date when the Ladd Syndicate was formed?

Answer. I can not fix that date purely from memory.

103. Cross-question. Give the exact date when you began experiments for the Ladd Syndicate?

Answer. I can not fix the exact date when I began from the Ladd Syndicate, purely from memory.

104. Cross-question. Give the exact date when you first conceived the idea of eliminating interference in wireless telegraphy?

Answer. I can not fix that exact date purely from memory.

105. Cross-question. Give the exact date when you first conceived the idea of producing a pure simple electromagnetic wave in a wireless telegraph transmitter?

Answer. That would be substantially the same date as the date of my conception of the invention of my patent No. 714756. I have already answered that I can not fix that date purely from memory.

[fol. 638] 106. Cross-question. Did you ever build or use a wireless apparatus such as is described in your two letters to Baker, defendant's Exhibits Nos. 2 and 3, before you wrote those letters to Baker?

Answer. No: I am quite certain that I did not build the apparatus described in those letters before writing the letters, but the elements and even some of the combinations described there, though not constituting the invention as a whole, I had caused to be constructed, and I used in my wired wireless experiments.

107. Cross-question. In your direct examination I understood you to say that the Stone system of your patent No. 714756 is used. As a matter of fact no apparatus manufactured by the Stone Co. is in use today; is not that so?

Answer. I am sure I do not know whether any of the Stone Co.'s apparatus is still in use or not. Certainly there is, or it is more than likely that apparatus embodying all the features of the invention of the disclosure of patent No. 714756 are in use in many parts of the world, though I do not mean to say by that, that such apparatus was constructed by the Stone Telegraph & Telephone Co.

108. Cross-question. What was the character of the spark gap which you actually used in your experiments, or commercial application of the Stone system?

Answer. We used a great variety of spark gaps. One of the favorite early forms was a multiple series spark gap. We also used multiple spark gaps. We used spark gaps with air blasts. We used very high-power air blasts, to quickly extinquish the spark. We used almost all the different spark gaps which have been either brought out by ourselves or others, except the so-called modern quenched gap. We never used a gap similar to that, which I have described as a quenched gap in this deposition.

109. Cross-question. Did you use rotary spark gaps?

Answer. We used rotary spark gaps in some of our experimental work, but not in our commercial sets.

110. Cross-question. What was the character of the detector used in your experiments?

Answer. I began, as practically everyone did in the early days, with the old filings coherer, and soon abandoned that for the microphone contact coherer of various types, including metal points on mercury. I at a very early date adopted for a time the bolometer. We used the thermal junction, electrolytic, crystal, and a variety of other detectors, in experimental work. In our commercial stations we used almost entirely, if not entirely, the Wallaston electrode.

111. Cross-question. When first, and where, did you use the metal filings coherer?

Answer. The metal filings coherer I first used in some experiments in the laboratory of the American Bell Telephone Co., merely as a matter of curiosity, without any attempt at working a wireless telegraph apparatus, but merely investigating the coherer principle as a matter of curiosity

The first time I used coherers in connection with my radio telegraph experiments was in my laboratory at 40 Lincoln Street, Boston. I can not fix the date of those experiments, as I testified, though I remember I looked up and refreshed my memory for the purpose of testifying in the Atlantic Communication Co. suit, and fixed that date pretty closely.

[fol. 639] 112. Cross-question. When first did you use the microphone detector in wireless telegraph work?

Answer. I can not fix that date exactly from memory.

113. Cross-question. When first did you use the bolometer as a detector in your wireless telegraph work?

Answer. I can not fix date definitely from memory, but I believe there are affidavits in some of my patents for bolometer detectors in which I made and fixed that date with certain precision.

114. Cross-question. When first did you use the electrolytic detector in your wireless telegraph work?

Answer. I can not fix that date with precision from unaided memory.

115. Cross-question. When first did you use the crystal detector in your wireless telegraph work?

Answer. I can not fix that date with precision purely from memory.

116. Cross-question. What substances did you usé as crystal detectors in your wireless telegraph work?

Answer. I used the ordinary crystals, such as galena, pericon. I did not undertake an investigation of a large number of crystals for their different properties.

117. Cross-question. When first did you use the Wallaston detectors in your wireless telegraph work?

Answer. From unaided memory I can not fix that date, but I believe that date is also established in the records of some of my patents relating to that type of detector.

118. Cross-question. Can you fix now from memory the date when first and for how long, you used any of these forms of detectors in your wireless telegraph work?

Answer. Not purely from memory.

119. Cross-question. Can you not fix from memory the date when first and for how long you used the various forms *fo* spark gaps which you have described?

Answer. I can fix the date of the use of the ordinary round polished balls, with pretty fair precision, considering the lapse of time, since those balls were used in connection with my experiments on radio telephony in the laboratory of the Bell Telephone Co., the records of which show that I was doing this work in April or May, 1899.

120. Cross-question. Other than that you can not fix the dates when and for how long you used the various forms of spark gaps which you have described?

Answer. The round ball spark gap was used by me for experimental purposes as long as my experiments with radio telegraphy continued in the work of the Stone Co. I remember the first form of multiple spark gap was in use*d* by me at my Cambridge station in 1903. I can not fix very

definitely the period in 1903 purely from memory in which the multiple spark gap was used, but my memory in that connection is refreshed by some of the photographs that I have recently seen of the apparatus at that station.

121. Cross-question. What do you mean by using the expression, "very accurately attuned circuits"?

Answer. I refer to the degree of precision with which we attuned circuits to one another in the Stone Co.'s laboratory, where a precision in such measurements of one-half of 1 per cent or a quarter of 1 per cent was insisted upon. In [fol. 640] certain instances a far greater degree of precision was attained, but in ordinary research work I insisted upon a precision of one-half to a quarter of 1 per cent.

122. Cross-question. What do you mean by the expression, "extremely loose coupling"?

Answer. An extremely loose coupling is a term which I have applied as relating to the transmitter when the coupling is sufficiently loose so that with an ordinary open gap and with no cooling except such as is obtained from an ordinary air blast, the oscillations developed in the primary and secondary circuits will be at one frequency only, and the radiated waves one wave length only. At the receiver an extremely loose coupling is one in which two circuits, such as an aerial and a closed resonant circuit, each separately tuned to the same frequency and brought into inductive relation with each other, will remain practically in tune without material change in the adjustment of either.

Perhaps this statement may need a little clarification. I will point out that if two circuits, such as in the aerial and the closed resonance circuit, be each attuned exactly to the same frequency and then be brought into close inductive relation with each other, both the circuits will be found to have their periods changed, and in order to secure a maximum response in a closed circuit from any waves received by the open circuit it is necessary to readjust the closed circuit or retune it, as it is popularly expressed.

When the coupling is loose no retuning is required, or else such retuning as is required is very slight.

I think that fully answers your question.

123. Cross-question. What do you mean by "an ordinary spark gap"?

Answer. An ordinary spark gap is composed, for instance, of two juxtaposed balls, of say, brass, or two mush-

ed electrodes with their mushroomed surfaces d, or two cylinders with their edges juxtaposed; these forms, with a moderate air blast passing be- juxtaposed surfaces.

oss-question. You do not include in the phrase park gap" the rotary spark gap or the quenched ?

No.

oss-question. Do you include the multiple spark

I might in some connections, where distinction is e; for instance, between the quenched type of gap p in which no great provision is made for quench- ark.

oss-question. What degree of coupling between y coupled circuits do you have in mind when using "extremely loose coupling"?

There is no definite coupling coefficient, so called, be regarded as the dividing line between tight coupling, because the amount of coupling at a ng station, for instance, in a so-called loosely stem may be greater when one kind of spark is

oss-question. Do you mean spark or spark gap?

Well, spark gap; when one kind of spark gap is and then another kind of spark gap is employed. speaking the greater the quenching action at the that is to say the less hysteresis of the spark, the coupling may be without developing the oscilla re than one frequency or—

128. Cross-question. Do you mean looser in- ghter?

No; quite the other way.

ss-question. Well, tighter?

Then the tighter the coupling may be without oscillations of more than one frequency or with ping electro-magnetic waves from the aerial of one wave length. After all that question is the f what constitutes loose coupling, the practical t the transmitter.

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ss-question. Can you state what degree of cou- had in mind when using the phrase "extremely ling"?

Answer. A degree of coupling which would insure a single frequency of oscillation at the transmitter and of resonance in the receiving circuit. In specific cases such a degree of coupling would have a definite value, but for different conditions of circuits this degree of coupling would vary. In the case of the transmitter the maximum coupling that could be called loose coupling —

131. Cross-question. No; I am talking about extremely loose coupling, Professor?

Answer. I will go on with that, and make the distinction. The maximum coupling that could be called loose coupling would be the coupling that would produce oscillations and waves of but a single frequency with an open or ordinary gap, and an extremely loose coupling would be a coupling considerably less than this maximum coupling.

132. Cross-question. I suppose you mean other conditions being the same?

Answer. Yes; that is right; and to be still more specific I remember that with some of the open gaps we used in my experimental station at Cambridge the maximum coupling at the transmitter that would produce a single-frequency wave was of the order of 3 per cent.

In a case of this kind an extremely loose coupling would be, say, of the order of 1 per cent, or a half of a per cent. Of course, any similar coupling would still be a loose coupling.

At the receiver the maximum coupling which would insure practically a single frequency of resonance will also vary with the conditions of the circuits, but I remember that in some of the sets that I used in my early work 2 or 3 per cent was the order of the coupling which effected this result.

With such a circuit a coupling of 1 per cent, or half of 1 per cent, or anything less than that might be called extremely loose coupling. I would say that extremely loose couplings actually were used in practice, and couplings of possibly as small as one-hundredth of 1 per cent actually were used when the necessity for excluding excessive inter- [fol. 642] ference was extreme. Such couplings at the receiving station would be called extremely loose couplings.

133. Cross-question. What are the conditions of the circuits which are to be taken into account in determining the degree of coupling in order to insure the emission or reception of but a single wave?

Answer. These conditions are exremely complex. They can only be determined by careful mathematical study of the relations of coupled oscillators. The theory of coupled oscillators was investigated by Bjrknes and Drude, Bjrknes's paper being published prior to the advent of radiotelegraphy and Drude's some time subsequently; but neither of these investigators took into account competently the effect of the resistance of the circuits, and this was never done until I published the mathematical theory of the subject in a presidential address before the Society of Wireless Telegraph Engineers, which presidential address was published in the Electrical Review and Western Electrician, of New York and Chicago, as near as I can remember, in January, 1903, and was reprinted in the Jahrbuch Drachlose der Telegraphie and in the l'Eclairage Electrique in the years 1905 and 1903, respectively, I believe.

Without reexamining these papers it would be very difficult to say exactly what the effect of each one of the elements or constants of the circuits had upon the degree of coupling which would give the reception of a single frequency or the emission of waves of but a single frequency. The subject is extremely complex.

Without, therefore, pretending to give a full answer to your question, I will say that considering the transmitter one of the principal conditions affecting the maximum coupling which will insure the radiation of waves with but a single frequency is the hysteresis of the spark. When this is large the maximum coupling which may be called loose coupling is correspondingly small, and conversely as the hysteresis of the spark is diminished the maximum coupling which may be called loose coupling or which will result in the radiation of waves of single frequency is correspondingly large.

The subject of the hysteresis of the spark and its effect in quenching the spark before two wave lengths or two frequencies of oscillation are fully developed was set forth by me in a presidential address before the Institute of Radio Engineers last year.

This, again, is not so simple a subject as to be dealt with except in a very technical manner.

With regard to the conditions at the receiver which would effect its response to a single frequency to the exclusion of

other frequencies, so far as the degree of coupling is concerned, that is also quite complicated, but the mathematical expressions determining that question in the matter of the tuning of the two circuits to each other are set forth in full in my United States patent No. 714756, to which I have referred in this deposition.

If I may be permitted to look at the mathematical expressions in that patent I think I can outline the conditions to which you referred in your question. May I refer to the patent?

134. Cross-question. Certainly. (Patent produced.)

Answer. The larger the resistance of the primary and secondary resistances the tighter the coupling may be which will insure response to a single frequency to the exclusion of all others, and the larger the reactances of the two circuits; that is to say, the larger the electrical stiffness of the [fol. 643] two circuits the tighter the coupling may be that will insure the resonant reception of waves of one frequency to the exclusion of all others.

It would also appear, though I can not be quite certain of it without computation, that, other things being the same, the smaller the frequency, or the longer the wave length to which the circuits are attuned, the tighter the coupling will be, capable of causing the circuits to respond to single frequency or wave length.

135. Cross-question. What do you mean by the expression "hysteresis of the spark"?

Answer. That expression is derived from the Greek and signifies a lagging behind. It is used in several phases of electrical work to indicate the lagging of a physical result after its physical cause.

Its most common application is to the magnetization of iron, which is very familiar as magnetic hysteresis, and the electrification of dielectrics or dielectric hysteresis.

There is a lagging behind in the resistance of an arc or spark, a lagging behind the current changes in the arc or spark.

The subject is set forth perhaps most simply and certainly most explicitly on pages 319, 320, 321, and 322 of defendant's Exhibit 6 in this case.

It is a somewhat complex phenomenon, and its results upon the oscillations in an electric circuit are extremely complex. These latter I have considered in the presidential address before the Institute of Radio Engineers last year.

Perhaps the simplest way to express what is meant by the hysteresis of the spark or arc gap is to say that the resistance at the spark or arc gap in a circuit is a function, or depends upon the amount of the current that passes across the gap during the spark.

If the resistance at any moment merely depended upon the current at that moment, then the resistance of the arc or spark would be set, not to have any hysteresis or lag, but it is found by experience that the resistance of the spark or arc at any moment "depends not only on the current flowing at that instant but also upon the current which has been flowing during an appreciable interval of time preceding it."

I am quoting the last passage of defendant's Exhibit 6, at pages 321, 322.

136. Cross-question. Then the greater the resistance of the spark the greater is the hysteresis or lag of the spark?

Answer. No. Usually I should expect the opposite to be the case, because the greater the resistance of the spark the quicker I should expect it to respond to a variation of the strength of the current of the spark.

137. Cross-question. The function of all spark-gaps, whether they be plain or open gaps, multiple gaps, rotary gaps, or quenched gaps, is that they serve as a trigger in starting oscillations, and to limit the potential applied to the condensers by the transformers' secondary; is that correct?

Answer. That is one function of the spark in radiotelegraphy. The subsequent function of the spark, after it has once begun to discharge, depends upon whether the system be of the impulsive excitation character, or of the loose-coupled persistently oscillating primary circuit type of excitation.

[fol. 644] 138. Cross-question. The ideal spark gap should have infinite resistance at the beginning of the spark and zero resistance during the continuation of the spark, and infinite resistance at the end of the wave train?

Answer. Such a spark would be an extremely desirable spark if it could be secured for a loose-coupled persistently oscillating primary circuit type of transmitter, and efforts were made at an early date to secure in practice just such a spark with considerable success in one type. Unfortunately, I do not believe that type of spark has ever gone into practical use.

139. Cross-question. For every different type of spark gap, plain or open gap, multiple gap, rotary gap, or quenched gap, other things being the same, there will have to be different degree of tightness or looseness of coupling required in order to emit or receive waves of a single frequency; is that correct?

Answer. So far as the receiving is concerned the problem will not be particularly affected by the particular type of spark gap used, other things being the same.

So far as the transmitters are concerned this will depend upon whether the impulsive excitation be used or whether the persistent primary oscillating system be used.

The mere use of a spark gap of a particular type will not determine upon which plan the impulsive excitation or the persistent primary oscillation excitation the transmitter will operate.

Taking the case of the persistent primary oscillation excitation, then the gaps which give rise to the least resistance hysteresis of the spark will permit of the use of the tighter coupling at the transmitter, and conversely those spark gaps giving rise to the larger resistance hysteresis of the spark will require the use of looser couplings.

Taking the case of the impulsive excitation transmitter, here the hysteresis of the spark is not the factor which determines the coupling which must be used.

The factor which determines that coupling is the production of a true or complete beat between the oscillations in the antennæ circuit and in the primary oscillating circuit.

Unlike loose-coupled persistently oscillating primary oscillator systems of excitation, in which any coupling looser than the maximum coupling will develop waves of a single wave length, the quench-gap system requires the use of some particular coupling in any given case, and that coupling, that critical coupling, is the coupling which will make the amplitude of the oscillatory current passing through the quench gap practically zero at the first beat, between the oscillations of the open and closed circuits at the transmitter.

If this critical coupling be departed from without making any other changes in the circuit to compensate for it, the spark will not quench at the first beat, and the excitation of the system will cease to be of the character of the quench gap or impulsive-excitation system.

In the case of the quench gap system therefor one operating as such, the type of the spark gap used, other things re-

maining the same, cannot be regarded as determining or materially affecting the coupling which may be used to effect the radiation of waves of but a single frequency wave length, so long as the spark gap is distinctly of the quench type; that is, of the type productive of extremely small resistance [fol. 645] hysteresis of the spark, as compared with what are often spoken of as the open spark gaps.

140. Cross-question. As I understand your last answer you have characterized the type of transmitter which you called impulse excitation as one having a quenched gap, and the transmitters which you called the loose-coupled type of transmitters as having open, rotary, or multiple gaps; is that what you mean?

Answer. No. I characterize these two different types of transmitters not by the type of spark gap used alone, because the mode of operation of the two is different, aside from the mere type of spark-gap device used.

You will note that I speak of the loose-coupled transmitters with persistently oscillating primaries as one type of practical radio transmission, in contrast to the impulsive excitation transmitters.

The distinction between the two transmitters is one of mode of operation rather than one of type of apparatus used.

It would be quite possible to use a quench gap in a transmitter and employ the mode of operation of the loose-coupled persistently oscillating primary circuit type of transmitter, and it would also be possible to use one of the older forms of spark gaps, such, for instance, as the rotary spark gap or the series open spark gap, with heavy air blast, in the impulsive excitation manner, in which the transmitter would be distinctly of the quench-spark type.

I am not sure that the efficiency of such transmitters could be as great as is commonly secured to-day by the use of quench gaps in the impulsive quench-gap devices, in impulsive excitation systems, and the open gap in the persistent primary oscillation loose-coupled transmitter system of operation.

In other words, the gap does not determine the system, but each type of gap is best adapted to one or the other of these two modes of operation.

141. Cross-question. If the gap does not determine the system what does determine the system?

Answer. The systems are the two extremely opposite modes in which a spark excited transmitted may be used for the development of waves of single frequency.

In the extreme case of the persistently oscillating primary loose-coupled transmitter, the coupling would be made very loose indeed, say a half of 1 per cent. The spark would be either so constructed or utilized that its resistance would be extremely small during the entire time of oscillation of the primary and secondary circuits, and within a wide range of from almost zero coupling up to, say, 1 per cent coupling the transmitter would operate to radiate waves of a single or substantially a single wave length.

On the other hand, in the case of the quench-gap system a certain definite coupling, other things being equal, would have to be used. This coupling would have to be sufficiently tight to produce a beat between the current through the spark gap after say five oscillations of the primary circuit, and at the same time the other constants of the two circuits, the aerial and primary circuit, would have to be so proportioned to each other and to the mutual induction that this beat in the current passing through the spark gap would be a complete beat or practically complete beat, so that in other [fol. 646] words the amplitude of the oscillatory current passing through that spark gap will become zero or practically zero at the beat.

These conditions find no parallel in the persistently oscillating primary loose-coupled transmitter systems. In these letter systems there in no critical mutual inductance, which must be used under given relations of the other constants. There is simply a maximum coupling which must not be exceeded, but which may be loosened to any desired degree without altering the mode of operation of the apparatus.

142. Cross-question. In your testimony you have used the phrase "five oscillations." Do you mean complete or half oscillations?

Answer. I mean complete oscillations.

143. Cross-question. That is, ten half oscillations?

Answer. No. The word "oscillation" implies a to and fro oscillation as a rule, when used by English speaking physicists, and certain foreign physicists have used the term "oscillation" to imply what we call half oscillations or reversals of current, yet even in European literature that use of the term is disappearing.

144. Cross-question. What do you mean by "tight coupling"? What values do you have in mind in using that phrase?

Answer. I believe I have already answered that question. Tight and loose coupling are purely relative terms, and per se I should not wish to place any specific numerical value on what is tight or what is loose coupling.

145. Cross-question. You have said in a previous answer that in what you have termed the loose-coupled persistent oscillating transmitters the maximum coupling must not be exceeded. What value do you have in mind in saying "the maximum coupling"?

Answer. That just illustrates my point, that most specific numerical value can be ascribed to the term "loose coupling" or "tight coupling," because in the loose-coupled persistently oscillating primary circuit transmitters the coupling which is properly called loose is that coupling which will result in the generation of oscillations and waves of a simple harmonic type, or have but a single frequency or wave length.

This degree of coupling will be different, dependent, as I have testified, upon a number of different considerations, and therefore what might be a tight coupling in one transmitter and therefore defeat the purpose of the device through its tightness of coupling would be loose or sufficiently loose for the successful operation of another one of the transmitters, and it would not be fair therefore to undertake to specify a given coupling as the limit of loose coupling, except for a particular station.

The term is generic as used in this connection and is characteristic of that whole class of transmitters which operate with the persistently oscillating primary circuit in which the oscillations of the primary circuit decay gradually, where the primary oscillating circuit and aerial have ample opportunity to effect each other's oscillations, so far as affects the development in each of two or more frequencies.

146. Cross-question. You have, I believe, stated that the character of the spark gap is not the factor which determines whether a transmitter be of the type which you have called impulse excitation transmitter or of the type which you [fol. 647] have called loose-coupled persistently oscillating primary transmitter, and as I understand your testimony you have said that the factor which does determine to which of these two types the transmitter belongs is the degree of

coupling between the primary and secondary circuits. Am I correct in so understanding it?

Answer. Not quite.

147. Cross-question. What, then, are the factor or factors which determine to which type of these two transmitters a given transmitter belongs?

Answer. The two types are characterized by a difference in their modes of operations, of which the general order of the coupling is only a result, and though looseness of coupling is one of the characteristics of the persistently oscillating primary transmitter capable of radiating simple harmonic waves or waves of a single wave length. While tightness of coupling, so called—that is to say, couplings of the order of 10 or 15 per cent, more or less—is one of the characteristics of the impulsive excitation transmitters capable of radiating waves of the simple harmonic type, yet the real difference is the difference in the mode of operation of these two systems.

In the first system, after the initial rush of current across the spark gap, a long persistent train of oscillations takes place in that circuit, and these oscillations in turn set up oscillations of corresponding frequency in the antenna or open circuit with which the primary oscillator is loosely coupled.

The oscillations in these two circuits react upon each other. If the coupling be sufficiently loose, the frequency of the oscillations developed into primary and secondary circuits will be substantially the same frequency or rate of vibration and no beats will occur in the oscillations of these two circuits, or if the frequencies of the oscillations developed in these two circuits be sufficiently different to produce beats they will nevertheless be sufficiently near to one another not to produce beats which will quench the spark of the primary oscillator before it has practically expended all the energy of the initial charge of the condenser, or else not sufficient to produce anything approaching a complete beat during the life of the oscillations of the primary oscillating circuit.

From this it will be seen that a considerable range or latitude exists in the amount of coupling which may be used in a given transmitter of this kind, without changing anything else.

On the other hand, in the impulsive excitation system in use the oscillations of the primary circuit after the first

rush of current across the gap are very quickly suppressed by the production of a beat in the current in the primary oscillator, owing to the reaction on the oscillations of that circuit, due to currents of a different frequency developed in the antenna circuit.

For the production of this rapid extinction of the spark in the primary circuit it is essential that the oscillations developed in the antenna or aerial radiating circuit by the oscillations and the primary circuit, be of a considerably different frequency from those of the primary circuit, and this is secured through the use of a so-called tightness of coupling between the two circuits, or through a detuning of the two circuits from each other, of say 10 or 15 per cent, as to their natural frequencies, and also through the adjustments of the circuits so that the beats between the currents, [fol. 648] due to the primary oscillator alone, and those due to the oscillations in the aerial, shall produce complete beats in the primary circuit, real or approximately real zeros of current amplitude in the spark gap.

There is, therefore, a relation between the coupling and the other constants of the circuit which determines the definite coupling for any particular circuit or combination of circuits at an impulsive excitation transmitter station.

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148. Cross-question. Will you please now answer my question and say what are the factors in a given transmitter which determine whether that transmitter is of the type which you have called the impulse excitation type, or of the type which you have called the loose-coupled persistently oscillating primary type? Is it the character of the spark gap employed or the degree of coupling employed, or both?

Answer. In this and my preceding answers I have, I feel, fully answered that question. I do not see how I could make the matter clearer, by any different answers than those I have already made.

I think I have completely distinguished between the two systems and shown that the distinction between these two types of transmitters is one of mode of operation and not one of mere types of apparatus.

I have even gone so far as to show that certain types of apparatus which are generally characteristic of one of these types of transmitters might be converted to the use of the other type of transmitter, and vice versa; but that they

would merely operate less efficiently in the type of transmitter for which they were not designed.

* * * * * * *

149. Cross-question. Does the character of the spark gap employed in a given transmitter determine whether the mode of operation of that transmitter is of the impulsive excitation type, or of what you have called the loose-coupled persistently oscillating primary type? Please answer that yes or no.

Answer. Not alone.

150. Cross-question. What other factor does determine it? Is it the degree of coupling? Please answer that yes or no.

Answer. No other one factor determines it.

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151. Cross-question. What other factor or factors decide the character of the spark gap?

Answer. I have already answered that the factor which determines the type of transmitter, that is to say, of the distinction of the two types of transmitters of which I have been testifying, is the mode of operation, and the fact whether or not the spark in the primary circuit is quenched after the first beat in the current passing through it.

* * * * * * *

152. Cross-question. I again ask you what factor or factors determine whether the mode of operation of a given transmitter is of the type which you have designated the impulse excitation type, or of the type which you have designated the loose-coupled persistently oscillating primary type?

Answer. The factor of whether there is developed in the primary circuit a beat, which causes the arc to extinguish [fol. 649] after the first beat in the current passing through it. The distinction between the systems is one — mode of operation and not one of apparatus, as I understand it.

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153. Cross-question. Will you be kind enough to answer the questions?

Answer. I have answered the question to the best of my ability.

154. Cross-question. Then I will put the question in another way: You have said that the character of the spark gap does not alone determine whether or not a given transmitter belongs to that class of transmitters which you have designated as impulse excitation transmitters or to that class which you have designated as loosely-coupled persistently oscillating primary transmitters. Does the degree of coupling between the two circuits determine, or is it a factor in determining, to which of these two types a given transmitter belongs? Please answer that yes or no.

Answer. It is only so far a factor as it determines whether a beat shall be produced in the primary circuit which will extinguish the spark on the first beat.

155. Cross-question. Will you please answer the question yes or no.

Answer. I do not believe the question can be answered yes or no.

156. Cross-question. What produces the beat in the primary circuit?

Answer. The beat in the primary is produced by oscillations induced in the primary circuit, from or by oscillations occurring in the secondary circuit, when said induced oscillations in the primary circuit are of equal amplitude with the principal primary oscillations at the time of said beat.

The exact relations of inductance capacity, mutual inductance, dissipation of energy in the different parts, etc., which will produce this condition, are extremely complex. They have never been completely and accurately determined mathematically. They are therefore incapable of being treated with precision.

The nearest approach that could be arrived at as to a statement of these conditions might possibly be by a study based upon Bjrken's mathematical theory which I have already referred to. I am not aware that anybody has made even this approximate study of those conditions. Once this study has been made, it would probably be possible to state exactly what the criteria are for the quenched gap mode of operation, just as it is possible to express exactly the criteria for the mode of operation of the loose coupled persistently oscillating systems; but I am quite sure that no expert could to-day offhand state the exact criteria in relation of the electrical constants of the system which would produce the mode of operation which we have

come to call the impulse excitation or quenched-spark system.

. . . .

157. Cross-question. Take the case of a transmitter provided with a plain or open spark gap on the one hand, and the case of a transmitter with a quench-spark gap on the other hand, all other conditions of the transmitter being the same, how would the degree of coupling between two such transmitters compare if both transmitters were designed and adjusted to emit a simple or pure harmonic wave, or what you call a wave of a single frequency?

[fol. 650] Answer. Practically, an engineer would, in the case of the plain or open gap, loosen the coupling between his primary oscillator and aerial or open circuit until he was able to detect but a single wave length in the radiated waves. When he had done this the order of the coupling he would have secured would be the order of say 2 per cent or less.

After reaching this value of the coupling he could further loosen it to any degree he pleased, and make still more sure of changed conditions of the spark gap not giving him two wave lengths.

In the case of the quench-gap device he would adjust his coupling, starting with a very close coupling and gradually loosening it until he secured a wave of a single frequency. The coupling he would reach in such a case would be of the order say of 10 or 15, more or less; but having secured this wave of a single frequency, any variation of the coupling, if sufficient to modify the mode of operation of the apparatus, causes the production of either two waves or at all events very inefficient operation of the apparatus.

When these two types of spark gap are used in radio transmitters the order of the difference in coupling I have indicated above, is about indicative of what occurs in practice.

I would not like to say offhand that some specially constructed, altogether experimental and special apparatus, might be gotten up for purely demonstration purposes, in which the relative magnitudes of the coupling might not be made different; but such an apparatus would not be typical, but would be extreme, and calculated to mislead rather than clarify the distinction between the two systems.

158. Cross-question. The primary function of any spark gap, whether it be an open gap or quenched gap, is to permit the condenser or condensers in the primary circuit of a wireless transmitter, to charge, and enable them to discharge?

Answer. That is its primary function.

159. Cross-question. And the object of using a quenched gap in a wireless transmitter is to prevent the retransfer of energy to the closed primary circuit after the energy has been supplied by the primary circuit to the open circuit in a requisite amount?

Answer. That is one object of using the quenched gap, another object being the securing of a persistent train of simple harmonic waves from the transmitter.

160. Cross-question. You are familiar with the so-called transmitters which were involved in the suit of Marconi against the Atlantic Communication Co.?

Answer. Yes.

161. Cross-question. They were quenched spark gap transmitters were they not?

Answer. They were.

162. Cross-question. The transmitters involved in the suit of Marconi against the De Forest Radio Co. were also quenched gap transmitters, were they not?

Answer. I believe so.

163. Cross-question. Now, referring to the crystal detectors, which you have used in the stations of the Stone Co., were these high-resistance detectors?

Answer. My recollection is that the crystal detectors used were all of the type which I had to connect across the [fol. 651] condenser to get the best results, and therefore I believe that they must have all been of the high-resistance type.

164. Cross-question. In the quenched-gap transmitters the spark is not quenched, and the primary circuit quenched to stop oscillating, until the energy has been transferred from the primary to the secondary; that is true, isn't it?

Answer. I believe that that is practically true. That is to say, such energy as remains in the primary circuit, is but a small fraction of the total energy of the discharge, and the nearer this relation is obtained, the more efficient is the operation of the apparatus.

165. Cross-question. How many complete oscillations were there in the primary of the Atlantic Co's. transmitter before the spark was quenched?

Answer. I do not remember with certainty that figure. I seem to remember that I gave that figure in an affidavit in the case of the Marconi Co. against the Atlantic Co., and without wishing to be understood as definitely remembering the number, I think it was seven oscillations.

166. Cross-question. Now, answer the same question with regard to the De Forest transmitters?

Answer. I don't remember having looked into the exact number of oscillations in the De Forest transmitters, but generally speaking the number of oscillations in quenched gap systems generally, as commonly used, is say four to seven; of that general order. This does not by any means imply that this is necessarily the number of oscillations which must be used. I am inclined to believe that the number could be, by slight circuit modifications, very much reduced.

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167. Cross-question. These defendants' transmitters which were involved in the Atlantic Communication Co. case or the De Forest Co. case were of the type which you have designated as impulse-excitation transmitters?

Answer. Yes.

168. Cross-question. Is it or is not true that with any form of spark gap whether it be a plain rotary, or quenched spark gap, that two or three wave lengths may be radiated, and that with any form of spark gap the circuit may be adjusted so that only one wave length is radiated?

Answer. Yes; though possibly with certain constants in primary and secondary oscillators, this could not be accomplished. I wish to modify my next preceding answer so far as this affects the De Forest transmitter. The exact arrangement and mode of operation of that transmitter I do not remember at the present moment. My best recollection is, however, that it was an impulse-excitation transmitter, but I can not remember absolutely that, without remembering the exact mode of operation as I do not at present.

169. Cross-question. The De Forest transmitter employed a quenched spark gap, as you remember it?

Answer. To the best of my recollection, it did, and also to the best of my recollection the excitation was impulse

excitation, but of this I am not sure. My best recollection [fol. 652] seems to me that there was an impulse excitation of a closed oscillating circuit which in turn produced forced vibrations in a radiating circuit, the period of which was very different from the period of the closed primary circuit.

170. Cross-question. What, if any, advantage is there in employing a tight coupling in a wireless transmitter as distinguished from a loose coupling?

Answer. Greater electrical efficiency and more persistent trains of waves have been secured recently by the so-called tight coupled impulse excitation transmitters than were attainable with the old loose coupled persistently oscillating primary transmitters.

171. Cross-question. Is it or is it not a fact that the employment of a quenched spark gap in a wireless transmitter, as contrasted with a plain or rotary gap, may permit tighter coupling between the primary and secondary circuits?

Answer. The coupling of any circuit transmitter may be tightened to any desired degree provided you do not care to radiate waves of a single frequency, that is to say, single harmonic waves, but if the condition of radiating simple harmonic waves be imposed then you are right, the use of a quenched gap with its much smaller hysteresis does not enable you to employ a system of impulse excitation by which waves of the simple harmonic type may be radiated at a much tighter coupling than is possible with the older system of the persistently oscillating primary. However, the contrast should not, I think, be made between the rotary gap and quenched gap, at all events not with the same force as is made between the ordinary open gap and the closed gap, for as a matter of fact the hysteresis of the rotary gap is very much less than that of the open gap, and in fact a good rotary gap I can imagine might be so constructed and used as to be almost, if not quite, as efficient in an impulse excitation system as what is conventionally called a quenched gap device.

172. Cross-question. I believe that you have used in your direct examination the phrase "resonant secondary circuit" in a wireless receiver. What do you mean by that phrase?

Answer. I mean a circuit comprising a condenser and an inductance coil or transformer coil, the inductance and capacity and other constants of the circuit being such that it responds resonantly to but a single frequency of im-

pressed force or to the waves of but a single frequency, to the exclusion or practical exclusion of waves of materially different wave length.

173. Cross-question. You have also used the expression in your direct examination of "tuned" and "attuned resonant circuits." Do you use them synonymously, or not?

Answer. Practically so. I generally use the word "attuned" to something, while using the word "tune" I often use it simply to indicate that it is adjusted to respond to a given frequency without referring to which frequency.

174. Cross-question. What do you mean by the phrase "sharply attuned" circuit?

Answer. The expression "sharply attuned" or "sharply resonant" indicates the degree of the attunement. A sharply attuned circuit responds very vigorously to waves of given frequency, and is practically opaque or nonresponsive to waves differing but slightly in wave length from this resonant wave length; while a circuit which is not [fol. 653] sharply attuned is one which, though having particular wave length to which it responds most vigorously, also responds sensibly to wave lengths in the neighborhood of that particular resonant-wave length.

175. Cross-question. What do you mean by the phrase "accurately attuned"?

Answer. I may mean in certain connections very sharply attuned, and in other connections, which I think could be distinguishable from the context, "the attunement of which is very accurately known."

176. Cross-question. And you have used the phrase in your direct examination "highly resonant circuit." What do you mean by that phrase?

Answer. A resonant circuit in which the resonant phenomenon is very pronounced. The expression in that sense is practically equivalent with sharply attuned resonant circuit.

177. Cross-question. Is it or is it not a fact that in the suit of the Marconi against the DeForest Co., to which we have referred and in which I believe you said you made one or more affidavits for the defendant, that you claimed that the DeForest transmitter was made and operated in accordance with your patent No. 714756?

Answer. I do not remember exactly the organization of the DeForest transmitter, nor do I remember having made the statement to which you refer.

178. Cross-question. I show you copy of the record in the Circuit Court of Appeals in the suit of Marconi *v.* DeForest Co., calling your attention to an affidavit of yours appearing on pages 330 to 344, inclusive, and ask you if this does not refresh your recollection and enable you to say whether or not you meant to contend that the DeForest transmitter's mode of operation was that set forth in your patent No. 714756; your affidavit is the one verified November 2, 1914?

Answer. I find under the last subject heading of my affidavit, namely, "Definitions," the only reference to my United States patent No. 714756. Under this caption of "Definitions" I refer to certain technical terms which I have used in the affidavit, such as "natural oscillations," "force oscillations," "natural period of oscillation," etc., "weeding-out circuits," etc., and then I say:

"The most complete and accurate definition of some of these terms, and the most accurate simple exposition of these subjects, particularly to radio telegraphy, is contained in my United States patent No. 714756, granted to me. I attach a copy of said patent to this affidavit and ask that the technical terms that I have herein employed be understood in the light of the explanations set up at great length in that patent."

I do not think that this would indicate that I have by this language intended to imply that the DeForest transmitter was, as to its mode of operation, necessarily disclosed in this patent specification, particularly as a very large part of the specification of that patent is given over entirely to a perfectly abstract discussion of the phenomenon of oscillations in simple oscillating and resonance circuits, and in coupled circuits, and as to the distinction between natural and forced oscillations in simple and coupled circuits and the effect on the natural periods produced in circuits by employing them together, and allied theoretical matters.

[fol. 654] The previous literature on the subject has been so entirely mathematical that I could only refer a mathematical physicist to it for definition of these terms, and an exposition of these phenomena, but I have always felt since the appearance of this patent of mine, No. 714756, that the subject is therein most clearly explained in language which can be understood by those merely skilled in the art of radio

telegraphy and not having the attainments of a mathematical physicist.

Whenever I have occasion to refer any one to a written exposition of these phenomena and a definition of these terms I refer them to this patent, where I made such an effort to get this very complicated subject clearly stated in accurate physical terms without a cloud of mathematics.

I do not mean to be understood as saying that the DeForest transmitter may not coincide with the invention of this patent, or may not be included under the terms of the claims of this patent. In fact, I believe that that transmitter should fall under the claims of the patent, though I could not make sure of it at this date without going over the subject very carefully.

I do not remember what my conclusions were on the subject at the time, even if I did reach a conclusion upon the subject.

179. Cross-question. When was it that you assisted Doctor DeForest in designing the transmitter involved in this suit?

Answer. I advised Doctor DeForest in regard to that matter, I think it was, about a year ago; I do not remember the date. I have no means of refreshing my memory as to the date just now. If I knew the date of the affidavit to which I have just referred I might be able to project backward and fix the date rather more accurately.

180. Cross-question. The affidavit is dated November 2, 1914, and in it you state:

"The object of the system designed by Doctor DeForest and myself is the same as that of all systems of radio transmission."

Can you now state when you assisted Doctor DeForest in devising this DeForest transmitter?

Answer. I think it was in the summer of 1914; the latter part of the summer of 1914 as I now remember it, that I advised Doctor DeForest as to the type of transmitter referred to in that affidavit.

181. Cross-question. Do you now say that the DeForest transmitter which you assisted Doctor Forest to design, and which was involved in this suit of Marconi against DeForest, did or did not employ the mode of operation described in the specification, excluding the claims of your patent No. 714756?

Answer. From my recollection of the transmitter I advised Doctor DeForest it was the combination of an impulse excitation and of a persistently oscillating primary circuit system of transmission. It was of a type to which I have already referred in this deposition, where a persistently oscillating primary circuit, extremely closely coupled, to an aerial or radiating conductor, tuned to a very different frequency from that of the primary oscillator, radiates substantially simple harmonic waves.

Now, if I remember correctly, my patent No. 714756 discloses only the type of transmitter employing loose coupling in which the aerial system and the primary oscillating [fol. 655] system of the transmitter are attuned to the same frequency in order to radiate waves of single frequency or simple harmonic waves.

Therefore, I do not believe, with this recollection of the transmitter Doctor DeForest used, and of my patent, that the transmitter Doctor DeForest used is the transmitter or falls within the scope of the particular transmitter specifically described in this specification; but it certainly fell under the general class of transmitters radiating simple harmonic waves, referred to in this patent, and not described as the preferred form.

182. Cross-question. I next call your attention to another affidavit of yours, verified November 2, 1914, in the same suit, of the Marconi Co. against the DeForest Co., on the Lodge and Marconi patents here in suit, and ask if you did not testify in this affidavit as follows:

"I assert positively and unqualifiedly, and I base my assertion on the knowledge I have gained through a great many years of practical experience in dealing with radio or wireless apparatus, that the essential character of defendants' apparatus and the mode of its operation as well, is radically different from the apparatus, arrangement, circuit connection and the mode of operation of the Lodge and Marconi patents in suit. If in an attempt to make it appear that the circuit arrangement of defendants' apparatus is the equivalent of the Lodge and Marconi inventions, it be contended that the radiating conductor is the path A, C^3, L^2, C^4, E, of Figure 1 of the blue print attached to the affidavit of Lee DeForest and J. S. Murphy, I assert that such contention is contrary to the fact, since the natural oscillations which take place through that path are purposely

made extremely small in order that they may not waste energy, while the useful oscillations, which cause the radiation to take place, are in a circuit A, C^3, C^4, E, and are oscillations forced on that circuit from the closed 'weeding-out' circuit, C^2, L^2, C^3. This circuit is essentially a 'weeding-out' circuit since it is a tune circuit without a spark gap interposed between the primary oscillating circuit 1 and the open radiating circuit A, C^3, C^4, E. The character of such 'weeding-out' circuits, their function and mode of operation is described in my United States patent No. 714756 attached to my supplemental affidavit in this case, and I shall therefore not dwell further at great length upon this subject. I will point out that the 'weeding-out' circuit 2 takes its energy from the primary oscillator and forces these oscillations on the open radiating circuit. This open radiating circuit A, C^3, C^4, E is purposely given a very different natural rate of oscillation from that of the 'weeding-out' circuit, in order that the forced oscillations may be of a single frequency, that they shall be practically free from any second frequency, such as would result if the open radiating circuit were in tune with the 'weeding-out' circuit or were to have nearly or approximately the same natural period as that of the 'weeding-out' circuit.

"The presence of this secondary frequency is a drawback to circuits or apparatus of the Marconi type, since the energy which flows into second frequency is not only lost so far as useful effect on the tuned receiver is concerned but serves to interfere with other radio stations in the neighborhood, which may happen to be trying to use waves of this second frequency or waves of nearly this second frequency for their own intercommunication. So harmful has this feature proved in the practice of the art in the past, [fol. 656] that the Government requires that radio stations, to pass inspection, shall, in the event of the presence of such a second frequency, be so adjusted and operated that the energy of the waves of this second frequency shall not be greater than 10 per cent of the energy of the useful frequency waves."

Did you so testify?

Answer. The quotation you make appears to be correct.

183. Cross-question. And in the same case did you also give a third affidavit for the defendant, namely, that verified October 23, 1914, on a motion for a preliminary injunction, and did you not in this affidavit testify as follows:

"The opinions of Judges Parker and Veeder are in substantial accord, in fact, in close accord in their interpretation of these two patents. Considering first the earlier of these two patents, namely the patent to Lodge, both opinions agree that the invention of this early and famous patent consists essentially in using an induction coil in the open or aerial circuit at both the transmitting and receiving stations. At the transmitting station the coil was used in order to cause the transmitter to emit a persistent train of waves, of a definite frequency, that is to say, a long procession of isochronous waves, instead of a highly damped wave train, or one containing only a very few successive waves such as a wave train which is extinguished after say three or four successively diminished waves had passed. At the receiving station the coil is *sued* in the aerial to attune the receiving aerial open circuit to the periodicity of the waves emitted by the transmitter. On this point Judge Veeder, after discussing the art prior to the Lodge patent very fully, proceeds to describe the invention of Lodge and to define its scope so clearly as to leave no doubt as to the interpretation to be placed upon the claims of this patent, however they be worded.

"Of this beautiful invention of an able scientist, Judge Veeder says:"

(The witness then quoted from Judge Veeder's opinion, the quotation being found at 213 F. R., p. 843, beginning at the second paragraph and continuing through to the beginning of the second paragraph on page 844.)

"I add hereto a sketch illustrating a Lodge construction by way of assisting the court in understanding the otherwise beautiful, clear discussion of the Lodge invention by Judge Veeder. In the foregoing sketch I have shown the open or aerial circuits of the Lodge patent as grounded at their lower extremities in order to bring it into line with the modern practice, and this is justified in view of the fact that Lodge, in his patent, states that one of the capacity areas may be the earth. In this sketch V represents the capacity area, L represents an adjus*ti*ble inductance coil, S represents a spark gap, and K represents a coherer or other detector of high frequency oscillations. Various means may be used to cause a spark at S, and various means may be used adjunct to K for the purpose of assisting it in its function of detecting the oscillations."

Did you so testify?

Answer. The quotation you make seems to be correct.

184. Cross-question. And did you also in this same affidavit testify as follows in regard to Marconi patent No. 763772 (p. 263):

[fol. 657] "This patent to Marconi, which is famous as the result of the decisions of Justice Parker and Judge Veeder, is generally known amongst the radio engineers, experts, and operators as Marconi's four-tuned-circuit patent. In this patent Marconi secures a radiation of persistent trains of waves in a manner different from that previously employed by Lodge. He secures a persistent train of waves by connecting his open aerial radiating circuit at the transmitter by means of a two-coil transformer, to a closed oscillating circuit, which is itself persistent, and he secures the transfer of energy from this persistent operating closed circuit to the aerial by attuning the aerial circuit by means of an adjustable inductance coil therein, so that it shall have the same natural rate of vibration as the persistent closed oscillating circuit. Marconi in this patent further secures his syntonic or resonant response at the receiving station by a different method from that employed by Lodge. He includes his detector in a closed persistently oscillating circuit connected to open aerial absorptive circuit by means of a two-coil transformer, and he secures the transfer of energy from the open aerial absorptive circuit to the closed persistently operating circuit by attuning the open aerial circuit by means of an adjustable inductance coil therein, so that it shall have the same natural period of oscillation as the closed oscillating circuit, comprising the detector K. Finally, Marconi secures the transfer of energy freely between the transmitting station and the receiving station by attuning the two circuits of each station so as to have the same natural periodicity of the two circuits of the other station. Thus the complete system comprises four circuits, each attuned to the same natural frequency by making the product of the capacity by the inductance of each circuit the same as that for each of the other circuits.

"Both Judge Veeder and Justice Parker have been quite clear in their statements of these facts, and their decisions make even the most ambiguous claims of the Marconi patent in suit easily interpretable as to their scope and real significance."

And did you not, after quoting claim 2 of the Marconi patent in suit and commenting upon it, then continue as follows:

"With the same characteristic clearness of thought and expressions as were evident in the passages I have previously quoted from Judge Veeder's opinion in relation to the Lodge patent, he says of the Marconi patent in suit."

You then quoted from Judge Veeder's opinion 213 F. R. at page 844, beginning with the paragraph at the bottom of the page and continuing to the end of the second paragraph, page 845, and then beginning again at page 847 at the second paragraph and continuing to the end of the first paragraph at the top of page 848.

I have correctly quoted from your affidavit in that case, have I not?

Answer. Yes; the quotation is correct.

185. Cross-question. You also gave one or more affidavits for the defendant in the sait of the Marconi Co. against the Atlantic Communication Co. on the Lodge and Marconi patents in opposition to a motion for a preliminary injunction?

Answer. Yes; I so remember.

186. Cross-question. Did you not in an affidavit in that case verified July 10, 1914, testify as follows:

[fol. 658] "I deny that the only important difference between the aerials at the date of the application for Lodge's patent and those of to-day resided in the spark gap of the early transmitting antenna. Further, the apparatus of Figure 3 of the Lodge patent is obviously inoperative, and Figure 4 is, to say the least, highly inefficient. It is so highly inefficient that no one would for a moment consider using it practically to-day."

Answer. The quotation is correct.

187. Cross-question. Two coil transformers in wireless transmitting or receiving sets are the equivalent of one coil or autotransformers, are they not?

Answer. In general, yes.

188. Cross-question. And a condenser coupling between two circuits in a wireless transmitter or receiver is an equivalent coupling to a one-coil or a two-coil transformer coupling?

Answer. No; I think in general not. I have carried the theory of the equivalents of conductive couplings to the in-

ductive couplings further in one of my papers than it has been carried by any one else.

I refer to a paper on "The coefficient of coupling of oscillation transformers," published in the Electrical World, I should say some five or six years ago, though in the case of conductively coupled circuits where the link between the two circuits is purely and simply an inductance coil, there is a very close analogy between the conductively coupled or autotransformer and the two-coil transformer, yet when the common branch of connecting link between the two circuits is a condenser, I am not certain that the equivalence can be found. The whole subject of this equivalence needs a reexamination. I am, in fact, at the present moment contemplating working out and publishing the mathematical theory of those equivalents for both the condenser conductive and inductants conductive connections, as well as the combination of these two in which the common connecting link between the two circuits is both a condenser and a coil.

189. Cross-question. At any rate, a condenser common to two circuits of a wireless transmitter does, of course, serve to transfer energy from one circuit to the other?

Answer. Yes; it is a mode of coupling the circuits and effects the transfer of energy to and fro between circuits.

190. Cross-question. Were these lectures which you gave at the Massachusetts Institute of Technology printed?

Answer. No; they were not; they were given extemporaneously.

191. Cross-question. Did you deliver a paper before the Canadian Society of Civil Engineers on the 9th of March, 1905, on the subject of "Interference in wireless telegraph," and is the printed paper which I now hand you a copy of such paper?

Answer. I read a paper before the electrical section of that society on that date and of that title, and what you hand me is a reprint of that paper, but I notice that one plate or figure or sheet of curves seems to be missing. The figure to which I refer is numbered Figure 10, and my recollection is that through some error Figure 10 was not included in the reprint, although it was included in the printed proceedings of the society and was also included in the reprint of the paper or report of the paper which appeared [fol. 659] in the local technical press shortly after I de-

livered the paper. I think I remember that the paper appeared in its complete form with that figure in the Electrical Review and Western Electrician, New York and Chicago, within a few months after I read the paper in Montreal.

192. Cross-question. Can you produce a copy of this paper which has the Figure 10 included in it?

Answer. I do not believe I have in my possession a copy of this paper, other than reprints, just like the one you have. I possibly could find it in the files of the Electrical Review or the Western Electrician.

Mr. Betts: Plaintiff's counsel offers in evidence the paper identified by the witness to be marked "Plaintiff's Exhibit A."

* * * * * * *

(Marked "Plaintiff's Exhibit A.")

193. Cross-question. Are you the John Stone Stone to whom was granted United States Letters Patent Nos. 767984 and 767990, dated August 16, 1904, copies of which I now show you?

Answer. I am.

Mr. Betts: Plaintiff's counsel offers in evidence printed Patent Office copies of the aforesaid two patents, and they are marked, respectively, "Plaintiff's Exhibits B and C."

(Marked "Plaintiff's Exhibits B and C," respectively.)

194. Cross-question. Did you testify for the defendant in a suit of the National Electric Signaling Co. against the Telefunken Co. on a patent to Fessenden, No. 928371, in September, 1911, as follows:

"Will you please give a concise statement of the principles involved in radiotelegraphy, as a practically applied art, including in your statement its genesis and evolution down to and including the date of Marconi's British patent No. 7777 of April 26, 1900, as respects its development after that date. I will ask you subsequently concerning each step thereafter.

"A. Referring first to the work of Marconi, it is safe to say that his British patent No. 12309 of June 2, 1906, was the first patent ever granted for an operative system of radiotelegraphy based upon a creation and detection of radiated 'Hertzian or electromagnetic waves.'"

Answer. I believe I made that statement.

195. Cross-question. Did you also testify in that same case as follows:

"Q. 28. Now, please state briefly the character of the apparatus constituting the next decided step in the art made by Marconi?

"A. The British patent No. 7777 of 1900 discloses the really important advances made in the art at that date. Marconi therein discloses a variable inductance coil in series in the antennae, or aerial structure, conductor, and the tuning condenser in shunt with the primary of the transformer in a tuned secondary of which is connected the detector and tuning condensers and inductance coils. Both the condenser in the primary and secondary and tuning inductance coils in the secondary, are made variable for the purpose of tuning the circuits with which they are associated."

Answer. I believe I made that statement.

[fol. 666] Cross-question. And in the same case did you not also testify as follows:

"Q. 10. Speaking generally, how do the subsequent advances in the art of radiotelegraphy, down to the present time, compare in relative importance to what was summed up in Marconi's two British patents of 1906 and 1900, to which you have referred, and others substantially cocontemporaneous with the latter?

"A. Though it is undoubtedly true that the apparatus substantially as it is clearly shown in the separate drawings of Marconi's British patent, is preserved in every efficient form of commercial apparatus, and of all systems used today, it is equally true that many of the elements in it were not of his invention."

Answer. I believe I made that statement.

197. Cross-question. And did you not also testify in that same case as follows:

"The first very clear and complete exhibition of the use of a continuously variable tuning condenser in shunt to the primary of a transformer in a wireless telegraph receiver, so far as I am aware, is contained in the specifications and drawings of the English patent to Marconi, No. 7777, of 1900."

* * * * * * *

Answer. I believe that is a correct statement of what I said.

198. Cross-question. When did you first disclose to Knight Bros., solicitors for the defendant in the suit of the Marconi Co. against the Atlantic Communication Co., the subject matter of your letters which are in evidence as defendant's Exhibits Nos. 2 and 3?

Answer. I can get you the exact date by referring to my files. I can do this because I wrote at that time to my patent attorneys, Browne & Woodworth, in Boston, in whose safe these letters were being preserved for me, and in whose safe the photolithographic copies of these letters were being preserved for me at my request, and I feel quite sure that I can find in my letter files a letter I wrote to Mr. Woodworth or to Mr. Browne or to Messrs. Browne & Woodworth asking them to send these letters on. Otherwise I cannot remember the date very specifically, except that I should say it was about a month prior to the time they were produced in court. It may have been earlier than that, but I should say it was about a month prior to the date of that production.

199. Cross-question. That is some time during 1916?

Answer. Yes; that would surely be in 1915.

200. Cross-question. In your affidavits which you filed in behalf of the defendants in opposition to the motion for preliminary injunction in the Atlantic Communication Co. case, and also in the De Forest Co. case, you did not produce or say anything about these Stone-Baker letters did you?

Answer. I do not remember having done so. I feel quite sure I did not.

201. Cross-question. Can you give the exact date when you conceived the invention described in defendant's Exhibits Nos. 2 and 3?

Answer. The exact date I cannot fix any closer than I have already in this deposition.

[fol. 661] 202. Cross-question. Can you give the exact date when you first disclosed to or discussed this invention with Baker, and the place where such disclosure was made?

Answer. I cannot state it any more closely than I have already in this deposition.

203. Cross-question. Can you give the exact time when you first disclosed this matter to your attorney, Mr. Browne?

Answer. No closer than I already have in this deposition.

204. Cross-question. Where did you disclose it to Browne?

Answer. Either at his office in Boston or at his summer home in Nantucket, Mass.

205. Cross-question. You have spoken of seeing Mr. James Maynadier in regard to this matter. Can you give me the exact time and place when and where you saw him?

Answer. I cannot place the time any closer than I have in this deposition. The place was at his law offices in the Sears Building, in Boston, Mass.

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206. Cross-question. Give the exact date when the Stone Wireless Telegraph Syndicate was formed?

Answer. I cannot give the exact date from memory, purely, any closer than I already have in this deposition.

207. Cross-question. What is the date as near as you can now fix it?

Answer. Early in 1901 or late in 1900.

208. Cross-question. Can you approximate the month?

Answer. No; I don't think I can approximate the month purely from memory. The date could, however, doubtless be fixed more closely by reference to some of our old records.

209. Cross-question. When was the $10,000 paid into the Stone Wireless Telegraph Syndicate?

Answer. It was substantially at the date of its formation.

210. Cross-question. When was the Stone Telegraph & Telephone Co. organized?

Answer. I cannot fix that date any more closely than I have in this deposition, purely from memory. Of course, the date of the formation of that corporation is a matter of record and could be exactly fixed, if necessary.

211. What is your recollection, your present best recollection, as to when the Stone Telegraph & Telephone Co. was incorporated?

Answer. Very nearly the first of 1902.

212. Cross-question. Can you approximate the month, from your present recollection?

Answer. To the best of my present recollection it was December, 1901, or January, 1902.

213. Cross-question. How long did the Stone Telegraph & Telephone Co. continue in active business?

[fol. 662] Answer. The Stone Telegraph & Telephone Co. continued in active business until some time in the latter part of 1909, or early part of 1910, though its activity was not very great at that latter period, and I can not fix absolutely from memory the date at which the company actually stopped doing any further business.

214. Cross-question. Was either the Stone Wireless Telegraph Syndicate or the Stone Telegraph & Telephone Co. operating wireless companies?

Answer. The Stone Wireless Telegraph Syndicate did no business whatever. It merely financed the experimental work I was doing at the time. The Stone Telegraph & Telephone Co. was purely a manufacturing company and development company. It never, per se, was a commercial operating company. The Stone Telegraph & Telephone Co. did, however, own the small company that operated the Isle of Shoals plant.

215. Cross-question. Did the Stone Telegraph & Telephone Co. manufacture and supply wireless apparatus while it was in existence to anyone except the United States Government?

Answer. Yes. It supplied apparatus to the Isle of Shoals Operating Co., which, however, was only one station, and it supplied a considerable number of apparatus to amateurs through a subsidiary company.

216. Cross-question. What was the name of this subsidiary company owning the Isle of Shoals station?

Answer. I do not remember the name of that company. I think it was the Isle of Shoals Wireless Telegraph Co., or some such name.

217. Cross-question. When was that company organized?

Answer. That company was organized, as near as I remember, in the latter part of 1905 or the early part of 1906. I fix that date by my recollection of the installation and operation of the Stone apparatus at the Navy radio station at Portsmouth, N. H., Navy Yard, with which the Isle of Shoals station communicated.

218. Cross-question. How long did the Isle of Shoals station continue to operate?

Answer. As long as the Stone Telegraph & Telephone Co. continued its operations; and whether it continued to operate after the Stone Telegraph & Telephone Co. went out of business or not I do not know.

219. Cross-question. Will you please give me the exact length of time in months or years during which the Isle of Shoals station was operated?

Answer. I have already testified that I do not know when the Isle of Shoals station ceased to operate. For all I know, it may be in operation to-day. I have never had occasion to look into the matter of its continued operation.

220. Cross-question. When did the Stone Telegraph & Telephone Co. cease to manufacture wireless-telegraph apparatus?

Answer. At the time it went out of active business.

221. Cross-question. When was that?

Answer. As near as I can remember, that was in the latter part of 1909 or very early part of 1910.

222. Cross-question. Why did the Stone Telegraph & Telephone Co. go out of active business?

[fol. 663] Answer. On account of lack of capital with which to prosecute its business.

223. Cross-question. You have testified, I believe, that you conducted experiments financed by the Stone Wireless Telegraph Syndicate during the year 1901, with a view to attaining a degree of selectivity of your system satisfactory to yourself; is that so?

Answer. That is a fact.

224. Cross-question. What degree of selectivity did you obtain which was satisfactory to you during these experiments?

Answer. I attained a degree of selectivity of better than 10 per cent. This degree of selectivity was not what I considered as high as I ultimately hoped to secure, but it was secured with the then accepted detector, namely, the filings coherer; and for such an erratic detector, creating as it does great perturbations in the receiving resonance circuit, I regarded it as sufficient.

225. Cross-question. Will you explain now what you mean by attaining a degree of selectivity better than 10 per cent?

Answer. The tests were made at that time at a receiving station comprising a filings coherer and telegraphic relays and sounders, the transmitter during the test remaining at a fixed distance from the receiver.

In these tests the four circuits of the transmitter and receiver were first placed in resonance, all of the same fre-

quency, and the amount of power at the transmitter adjusted until the receiving telegraphic apparatus responded satisfactorily, the amount of power being used being such that any diminution of the power would cause the telegraphic apparatus to cease responding satisfactorily. Then the two circuits of the transmitter, while still using the same power, were attuned to a frequency 10 per cent different from that previously used, that to which the two circuits of the receiver were attuned, and the transmitter was again operated.

If during the course of the test the receiving apparatus failed to respond at all to the transmitter with its second adjustment the system was said to have a selectivity of 10 per cent.

In all these tests the transmitter was first used with the frequency and wave length corresponding to that of the receiver, and then used with frequencies and wave lengths 10 per cent greater and 10 per cent less than the frequency to which the receiver was attuned.

226. Cross-question. Where was the receiving station and the transmitting station?

Answer. They were at the opposite ends of a long room being about 50 feet apart.

227. Cross-question. You have stated that the Stone Telegraph & Telephone Co. was organized in December, 1901 or January, 1902. How long previous to the organization of that company did you succeed in attaining a degree of selectivity of your system satisfactory to you?

Answer. I do not remember the date definitely but it was in the latter part of 1901 that I got sufficiently consistent results at 10 per cent selectivity to suit myself, as near as I can now recollect.

228. Cross-question. Well, was it subsequent to August 1, 1901?

Answer. I can not undertake to specify the month. It was in the latter part of that year, as near as I can remember.

[fol. 664] 229. Cross-question. Well, as near as you can remember was it later than August 1, 1901?

Answer. I should think so.

230. Cross-question. When was it that Professor Cross was asked by you to make a report on your experiments?

Answer. I do not remember the date. It was in the latter part of 1901, as near as I can remember.

231. Cross-question. When was it that Dr. Louis Duncan was asked to witness or make a report on your experiments?

Answer. Doctor Duncan was asked to make several reports on my work. The first time he was asked to report upon this work, as near as I can remember, was in the latter part of 1901. Subsequently he made more extended reports on the more elaborated apparatus and system.

232. Cross-question. Did Professor Cross witness your experiments; if so, when first?

Answer. Professor Cross witnessed my experiments in my laboratory in 40 Lincoln Street prior to the formation of the Stone Co.

233. Cross-question. That is some time in the latter part of 1901?

Answer. Yes, as near as I can remember.

234. Cross-question. And when first did Doctor Duncan witness your experiments?

Answer. I do not remember Doctor Duncan's witnessing my experiments. I believe that he did make an examination of my apparatus and its working at a time when I was not in Boston. The best of my recollection in regard to Doctor Duncan's investigation of the Stone system is that the actual apparatus and its working was exhibited to him by my assistant, not Mr. Baker at the Lincoln Street laboratory, but one of my assistants at the Charles River embankment stations after the formation of the Stone Co.

235. Cross-question. What was the name of this assistant?

Answer. To the best of my recollection I was not present and I do not know who the assistant was. It might have been E. R. Cram or it might have been Mr. F. A. Kolster. I do not remember if I ever knew which one of these gentlemen showed him the apparatus. In fact, the apparatus might have been shown by him by my patent attorney, Mr. Alexander P. Browne, of Boston, 60 Congress Street, Boston.

236. Cross-question. Did either Professor Cross or Doctor Duncan make reports of your experiments in writing?

Answer. I do not remember whether Professor Cross made a report in writing or not. Doctor Duncan made at least two reports in writing, as I remember it, and published one article on the Stone system in one of the American electrical journals.

237. Cross-question. The next step as I understand it, which you took, was the erection of two experimental stations on the Charles River embankment at Cambridge, Mass.; is that right?

Answer. After the formation of the Stone Co. my recollection is that the next step was the erection of two stations on the Charles River embankment.

238. Cross-question. How far apart were those two stations?

Answer. Those two stations were about a quarter of a mile apart and had mere 40-foot telegraph poles for masts.

[fol. 665] 239. Cross-question. When was the erection of those stations begun?

Answer. To the best of my recollection early in 1902.

240. Cross-question. Can you give me the month?

Answer. No, I should hesitate to try to fix it more closely.

241. Cross-question. When were those two Cambridge stations completed.

Answer. A very short time after they were started, as they merely consisted of match board frame buildings about 10 feet square, covered with waterproof paper.

242. Cross-question. How long did you or the Stone Co. continue to work those stations?

Answer. One of these stations was enlarged very shortly after it was built, I should say two or three months after it was built, so as to make it a two-room building some three times as large as it originally was, and having an 80-foot mast. Later the mast was increased to about 180 feet. This was some three months after the 80-foot mast had been erected, as near as I can remember. As soon as the high mast was erected the operations between the two stations were practically discontinued except for minor tests of detectors, etc., the plans for all other tests being arranged for the longest distances, either between the Cambridge station with its 180-foot mast and the navy yard station at Charlestown, Mass., or to the Stone station at Lynn, Mass. The enlarged Cambridge station continued in use until the Stone Co. went out of business. It was used both for test purposes and occasionally for reporting Marblehead yacht races, when interference was too great for the navy yard station at Charlestown to secure the clear reception of these messages. In a sense this might have been regarded as commercial operations of the Stone Co., except, so far as I

remember, these reports of the yacht races were not paid for, but the station was merely used to help out other stations in this connection.

243. Cross-question. Were each of these two Cambridge stations both transmitting and receiving stations?

Answer. No. Only one of them, the one that was enlarged, was ever used as a transmission station, as near as I can remember.

244. Cross-question. How long was the other, or smaller station, worked after it was completed?

Answer. It was used, as near as I can remember, for about a year, off and on.

245. Cross-question. What was the character of the spark gap at the Cambridge transmitting station?

Answer. It was very greatly varied during the course of the experiments. One type of spark gap used was large hollow brass balls filled with water.

246. Cross-question. As I understand it the Stone Telegraph & Telephone Co. did not begin to enter into commercial work, that is to say, furnishing sets of apparatus, but devoted itself to the necessary electrical tests and to research work, until some time in 1905; is that correct?

Answer. The Stone Co., as near as I can remember, did no commercial work until early in 1905.

247. Cross-question. When was it that the Stone Co. supplied apparatus to Charlestown Navy Yard?

[fol. 666] Answer. As near as I can remember it was in the early part of 1905.

248. Cross-question. Can you fix the date any more definitely?

Answer. No; I have a sort of a recollection that it was in April.

249. Cross-question. Did the Stone Co. sell its apparatus to the Government for the Charlestown station, or what was the arrangement?

Answer. As I remember the arrangement, it was the Stone Co. sold its apparatus to the Navy Department for the Charlestown station.

250. Cross-question. When was the station at Lynn erected, to which you have referred?

Answer. To the best of my recollection that was in 1903.

251. Cross-question. The purpose of the erection and operation of that Lynn station was to conduct tests of your system with the enlarged station at Cambridge?

Answer. Yes.

252. Cross-question. What was the amount of power used in the Cambridge enlarged transmitting station?

Answer. That station had various power equipments. I do not remember what the first power was. It must have been small, because with the original 40-foot mast, no very considerable power could have been radiated from the antennae, and therefore no considerable power equipment could have been used. As the height of the mast was progressively increased the power equipment was increased, and I remember supplying the power to the station was increased in capacity several times.

253. Cross-question. Why was it increased in capacity several times?

Answer. Because as we increased the height of the mast and therefore the capacity of our radiating aerial we were able to dispose of and radiate more energy, and it became necessary to use more power.

254. Cross-question. When was the Stone apparatus supplied to the Portsmouth (N. H.) station?

Answer. To the best of my recollection early in 1905. That is to say, I think that the equipment took place early in the summer of 1905. As I remember it, there was some delay in the equipment of that station after the Stone apparatus was delivered there, but I cannot remember that very distinctly.

255. Cross-question. Did the Stone wireless apparatus which was supplied to the Charlestown and Portsmouth stations comprise both transmitting and receiving apparatus or sets?

Answer. It did: also the power supply apparatus, as near as I can remember it, at both stations.

256. Cross-question. What was the rated kilowatt capacity supplied to these two stations?

Answer. I forget now whether they were 3 or 5 kilowatt. I rather think they were 3 kilowatt.

257. Cross-question. Was the Lynn station a transmitting station or a receiving station?

Answer. So far as I can remember the Lynn station was purely a receiving station.

258. Cross-question. What was the height of mast or antennae wire at this station?

Answer. I think it was about 100 feet.

[fol. 667] 259. Cross-question. Did you take part in the installation of the Stone apparatus at either the Portsmouth or the Charlestown Navy Yard stations?

Answer. No. I visited both stations to inspect the installation, as near as I can remember it, only after the installation had been made.

260. Cross-question. Did you visit either one or both of the stations more than once?

Answer. I visited them both more than once at different times.

261. Cross-question. When did the Stone Co. supply its apparatus to U. S. S. *Lebannon?*

Answer. As near as I can remember that was in the year 1905 also.

262. Cross-question. When did the Stone Co. supply its apparatus to the battleships *Georgia, Minnesota,* and the other battleships you referred to in your direct examination?

Answer. They were supplied with their apparatus later than the *Lebanon.* I do not remember the years in which these battleships were equipped. The *Minnesota* and *Georgia* were equipped first, as I remember it, possibly about 1906. Later other battleships were equipped. I think the *Washington* and *Tennessee* were amongst some of the ships we equipped in the Navy, but I do not remember the dates at which these equipments were made.

263. Cross-question. Am I correct in understanding you to testify that the apparatus which you used at the two Cambridge stations and also at the Lynn station, and also at the Charlestown and the Portsmouth stations, and the Stone apparatus which you supplied to the Navy Department for use on its vessels, was designed to operate in accordance with the description of your patent No. 714,756?

Answer. Yes, except, of course, that at Cambridge experimental stations, when purely research work was going on, all the varieties of circuits described in some hundred or more of the Stone Co.'s patents were set up and tested, and some of these did not necessarily involve the features and mode of operation of the Stone patent No. 714756, but for transmission purposes and reception purposes, aside from research and experimental work, the apparatus and its mode of operation was that of the disclosure of my patent No. 714756. I think this was invariably the case.

However, on occasions when the disturbance from atmospheric and other causes was practically absent, and my assistants wished to receive with the maximum degree of sensibility irrespective of freedom from interference, they would often transfer the detector and its associated indicating device from the local resonance receiving circuit and connect it directly into the aerial circuit, as in the old Marconi direct antennae arrangement, this being more sensitive than the coupled circuit arrangement, but though enormously susceptible to interference.

Again, when atmospheric and other disturbances were not present, or were practically absent, my assistants would introduce the spark gap directly in the aerial and use the aerial after the manner of the early Marconi open aerial, in order to more directly radiate the energy and secure added range to the station; but even in that latitude the times in which this could be done with advantage were very few, since both of these arrangements were inconsistent [fol. 668] with the exclusion of interference, both from atmospheric causes and from other stations.

By Mr. Scull:

264. Cross-question. You spoke of the old Marconi direct antennae. Is this arrangement to which you refer sometimes known as the "Plain antennae"?

Answer. Yes; it is the plain antennae, and in addition to that we always had it attuned to some particular frequency, so we also had a tuning coil in the antennae.

By Mr. Betts:

265. Cross-question. In the apparatus which the Stone Co. put out what means were adopted or used to ascertain whether or not the closed primary circuit was tuned with the open secondary circuit of the transmitters and the closed secondary circuit of the receivers were tuned to the open circuit of the receivers?

Answer. I have already answered that question. With respect to the transmitter the loosely-coupled primary oscillator was tuned to the period of the fundamental of the aerial by placing a spark gap across the inductance coils, and secondary transformer of the aerial, or a portion of it, and the frequency of the oscillations of the primary adjusted until a maximum spark could be obtained across the test

spark gap in the aerial circuit. In these tests a very large number of individual sparks were taken with each adjustment of the apparatus, and it was found possible to attune these circuits to each other with the precision of one-half of one per cent or better by this method. By the use of a still greater number of individual sparks in each test we were able to attain even greater precision in the attunement of these circuits to each other, but a half of one per cent was, as I remember it, the degree of precision upon which I insisted in most of our laboratory determinations.

With respect to the receiving station the adjustment of the local resonance circuit with which the detector and indicating device were associated, the attunement of this circuit to the frequency of the waves to be received was usually accomplished merely by making the adjustments with the guide as to the precision of reception of the waves by the indicating device, that is, telegraphic relay and sounder or telephone receiver, as the case might be.

In these tests the coupling between the aerial and the receiving circuit was loosened until a certainty of response was not secured except at one particular frequency. The circuit was generally left in this condition of attunement during the test, as it was generally considered best to receive with the minimum possible coupling between the circuit that would enable an operator to read the signals easily.

In some of the early tests where a coherer of the filings type was used in the local resonance circuit, causing as it did erratic perturbations of the constants of the circuits, resort sometimes was had to tuning the local resonant receiving circuit at the transmitter by the spark method, and taking it over to the receiving station and keeping it in that condition of attunement, but that method was never quite satisfactory, in fact no resonant circuit attunement where a coherer is associated with the circuit is ever quite satis- [fol. 669] factory. The greatest precaution has to be taken to maintain anything like 10 per cent selectivity in such a circuit.

Later, when wave meters and hot wire ammeters became common, I believe my assistants tuned commercial sets, that is to say the sets with which they equipped the navy yards and battleships, by means of hot-wire ammeter readings in the transmitting antennae as is pretty generally the custom now in all wireless stations.

With the detectors which were used in commercial sets the tuning of these circuits at the receiver was always accomplished by the first method I have described with respect to the tuning of receivers.

To be specific, in this method, with the coupling quite loose, the variable condensers were manipulated and the coupling loosened until at only one position of the condensers would the incoming signals be easily legible, and that constituted the tuning of the local resonance circuit at the receiver.

The antennae circuit of the receiver was attuned as a rule by the adjustment simply of the inductance in that circuit until the maximum signals were received in the local resonant receiving circuit indicator.

In the early laboratory tests at 40 Lincoln Street the two antennae circuits, that at the transmitter and at the receiver, were maintained identical, and in that way these two antennae were always in tune.

Generally speaking, the tuning of an antennae either to transmit or receive a given wave length was a matter of careful calibration once and for all, and thereafter if any change was to be made in the antennae it was simply made by connecting in the antennae at a definite marked point on the antennae coils.

In commercial apparatus also corresponding points for such loose-coupled tuning were marked on the primary coils in order that these adjustments might be quickly made without going through these tests to which I have referred.

266. Cross-question. What was the character of the detector which was supplied to the receiving sets to the Navy Department?

Answer. It was a little device first made and described by Doctor Wallston about the year 1800, as I remember it.

It was a device he got up for demonstrating that the discharge of a condenser would produce electrolysis, the discharge of a Leyden jar, not having previously been supposed to be capable of producing electrolytic action.

This is a device which consisted of a very fine platinum wire sealed in a glass tube, the end of the glass tube containing the wire sealed in it being then ground off flat, so that only the flat end of this extremely fine platinum wire would be exposed.

The wire Doctor Wallston used was so fine as to be practically invisible or almost invisible even to the naked eye

of the keenest sight, and was ingeniously made by casting a fine platinum wire in a jacket or surrounding cylinder of silver. The resultant cylinder or compound wire so formed, was then drawn down until it was itself a fine wire. The resulting end of this wire was then placed in a bath or solution which would attack and absorb off the silver, but not attack the platinum wire. In this way an extremely fine platinum wire was produced.

Doctor Wallston used this electrode in a little cell, of which the electrode was one terminal, the other terminal or [fol. 670] electrode being a flat piece of platinum and the electrolyte, I believe, as near as I can remember, was an acid solution.

We used the same structure in most of our commercial sets.

267. Cross-question. Did you use any crystal detectors in these commercial sets?

Answer. I believe some crystal detectors were used in commercial sets, but my impression is that these were not furnished by the Stone Co., and if used were used by operators who preferred that particular type of detector; and I think I am fairly clear in my recollection that the Stone Co. never put out any crystal detectors.

268. Cross-question. To what precision or degree of accuracy was the closed receiving circuit attuned to the open receiving circuit in the Stone commercial sets, after the wave meters and hot-wire ammeters came into use?

Answer. The degree of precision depended upon the operator using a set. These sets were capable, particularly when equipped with the "weeding-out" circuit, as I believe all of them were, of the most extraordinary degree of selectivity which is indicative of the degree of precision with which the tuning was accomplished.

I remember that in one of these sets a secrecy transmission test was conducted which involved the receiver, being capable of receiving Morse signals at as high a speed as 20 words a minute on one frequency, and not hearing any signals whatever which were coming in at equal strength on a wave length differing by 2 per cent from that on which he was receiving, there being two such interfering wave lengths , one 2 per cent longer and on 2 per cent shorter than the wave length upon which he was receiving.

This could only have been accomplished with an extremely loose coupling, and in fact it was accomplished

with a very extremely loose coupling, and indicates that the precision of tuning was quite as great as any of the attunements we could make in our laboratory test apparatus.

The local circuit must have been attuned to the antennae with the degree of precision far greater than one-quarter of 1 per cent in any such apparatus.

As commercially used by the Navy operators the "weeding-out" circuit was rarely ever made use of, and no such degrees of tuning were sought by them, so far as I am aware. In fact, often they made use of a provision whereby they could connect the detector and its associated apparatus directly into the aerial in order to secure greater sensitiveness at the sacrifice of almost all the selectivity resulting from the tuning of the apparatus.

269. Cross-question. When was it that wave meters and hot-wire ammeters came into use for wireless or telegraphy purposes?

Answer. The first wave meter that came into use at one of my stations was, as I remember, very late in 1905, or sometime in 1906, at the Charlestown Navy Yard station, I believe.

I do not remember whether or not I originally installed a hot-wire ammeter in the Charlestown, Mass., and Portsmouth, N. H., stations. I did not do so unless the Government's specifications call for it at that time.

270. Cross-question. Generally speaking, to what degree of accuracy or precision did operators using the Stone [fol. 671] apparatus tune the closed receiving circuit to the open aerial circuit after the wave meters and hot-wire ammeters came into use for that purpose?

Answer. Of my own knowledge I do not know. They should have attuned them to the same frequency, with a considerable degree of precision, because it was the custom of the Stone Co.'s engineers to calibrate the apparatus so that if the plugs connecting the antenna to its coils, and the primary condenser to its coils, were placed in the posts marked, and the coupling loosened to the specified extent, the attunement should be correct to within one-half of 1 per cent; but I am not personally aware whether the Government operators followed the instructions they received in this regard carefully. Of course, if they put the plugs in the specified posts and tightened the coupling too much, two frequencies of the closed and open

circuits world be forced apart, even thought they were originally within one-half of 1 per cent of each other.

271. Cross-question. Can you tune the closed transmitting circuit to the open transmitting circuit, or the closed receiving circuit to the open receiving circuit of a wireless set, by merely varying the degree of coupling between the two respective circuits?

Answer. Only in a very restricted sense can you do so. If the inductances and the capacities of the circuits are such that they will be attuned to each other at a very loose coupling, while on the other hand the coupling is tight, then by loosening the coupling the necessary amount the periods of the two circuits will more and more approach each other as the coupling is loosened, until finally the periods become the same. To that extent you can attune two circuits to each other by the variation of the coupling.

In other words, assuming two circuits tightly coupled, but whose capacities and inductances are such that if they were loosely coupled with each other they would have the same frequency, but being tightly coupled have different frequencies natural to each, then if you loosen the coupling sufficiently, as you do so the natural frequencies of the two circuits will gradually approach each other until finally when the desired degree of looseness of coupling is attained, the frequencies of the two circuits will be the same or substantially the same.

It is perhaps necessary for the extreme accuracy demanded in discussing physical questions of this character, to say that theoretically, that is to say, under the old logarithmic decrement theory, two circuits which have any coupling with each other at all can not have exactly the same frequencies; but this is a matter of no particular moment, since when the coupling of circuits is made what we call loose, in practice, they are found to have so nearly the same frequency that no difference can be detected.

272. Cross-question. When did Mr. Baker enter the employ of the Stone Telegraph & Telephone Co.?

Answer. My impression is, as near as I can remember, he was my personal assistant at the time the Stone Co. was formed, and was then transferred to the payroll of the Stone Co.

He then, after a relatively short period of time, as near as I can remember, left the employ of the Stone Co., and

devoted his entire attention to the Ladd Syndicate work, and was subsequently again employed for some special work by the Stone Co.; either once or twice, as near as I can remember, Mr. Baker was reemployed by the Stone Co. [fol. 672] for some special purpose, but I do not remember the dates of his goings and comings.

273. Cross-question. Referring to defendant's Exhibit No. 2, where was the original of this letter written?

Answer. It was written, as near as I can remember, in my office in Boston. I think it was in my Phillips Building office in Boston.

274. Cross-question. Where was the original of defendant's Exhibit No. 3 written?

Answer. My impression is that that also was written at my office in the Phillips Building in Boston. At all events the letters were written in Boston and either at my office or at my home.

275. Cross-question. Were these two letters sent to Mr. Baker at the same time?

Answer. I certainly do not think they were. I think they were, I am quite certain that they were sent on the days they were written, but of course I could not be quite positive about that.

276. Cross-question. How were these two letters sent to Mr. Baker by you?

Answer. I made no particular note of how they were sent. I have no reason to suppose that they were sent any other way than through the mails, as ordinarily would be the case. That would be the best of my recollection.

277. Cross-question. When did you receive these two letters back from Mr. Baker?

Answer. The best of my recollection is that Mr. Baker produced these two letters that I wrote him some two or three years later, when my patent attorney, Mr. Browne, had occasion to make use of them in connection with the prosecution of one of the applications for one of my other patents. However, I am quite sure that I can fix the date within a day or two absolutely by papers on file. I think it quite certain I can fix that date very closely indeed.

278. Cross-question. From your present recollection can you fix the date when Mr. Baker returned the originals of defendant's Exhibits Nos. 2 and 3 to you?

Answer. I can not fix the date any closer than I have testified. He, as I remember it, returned them not to me

directly, but to the Stone Co.'s office at the time that I refer to, and under the circumstances that I refer to.

279. Cross-question. Referring to the letter marked "Defendant's Exhibit No. 2," is the original of that letter, including the date, signature and address, and contents, in your own handwriting?

Answer. Understanding by the expression "My dear Baker" you mean the address, all are in my handwriting.

280. Cross-question. And was the date "June 30, 1899," put on by you on that day?

Answer. Undoubtedly.

281. Cross-question. In writing the date, the signature, the contents of this letter, did you use the same pen and ink?

Answer. I presume so. I have no reason to doubt that I did.

282. Cross-question. Was it a stub pen or a pointed pen that you used?

Answer. I almost invariably use a stub pen, if I can get it, so it must have been a stub pen.

[fol. 673] 283. Cross-question. Did you use a blotter to blot the date or the contents or the signature on the original of defendant's Exhibit No. 2?

Answer. I have no recollection in the matter.

284. Cross-question. Did you write in your own handwriting the date, the contents, and the signature on the original of defendant's Exhibit No. 3?

Answer. Understanding "My dear Baker" to mean what you call the address, I did.

285. Cross-question. And you wrote the date "July 18, 1899" on this letter on that day?

Answer. I have no reason to doubt that I did. It is my custom to date letters the day that I write them.

286. Cross-question. After the originals of these two letters, defendant's Exhibits Nos. 2 and 3, were returned by Mr. Baker to the Stone Co. to whom were they returned?

Answer. They were returned, as I remember, to my patent attorney, Mr. Alexander P. Browne, at 31 State Street, in the company's offices, which were adjoining Mr. Browne's offices.

287. Cross-question. When did you come into the possession of the originals of these two letters again?

Answer. These letters were kept together with the photolithographic copies of them in the safe of the Stone Co., I remember, during the entire active existence of that company. After the Stone Co. went out of business, these letters and the photolithographic copies thereof, were kept, as I remember, it in the safe at my office, and at the date which I can not definitely place, they were transferred to the safe in the office of my patent attorney, Mr. Alexander P. Browne. They remained there until I called for them at the request of the counsel of the Atlantic Communication Co., when that company set up its Stone defense, in the suit brought against it by the Marconi Co., to which I have already testified.

288. Cross-question. When did you personally see the originals of defendant's Exhibits Nos. 2 and 3 after you transmitted them to Baker?

Answer. As I now remember it, I saw Mr. Baker when he came into the Stone Co.'s office to produce these letters, and I think that I inspected them at that time, but I can not be sure of that. I have no memorandum showing that I was present at the time Mr. Baker produced the letters at the Stone Co.'s office. I have simply an indefinite recollection that I was there and took part in the conference that was had with regard to them, and in regard to Mr. Baker's making any affidavit with respect to them in connection with the prosecution of one of my applications for patents in the United States Patent Office.

289. Cross-question. What was the date of that conference when Mr. Baker took the originals of these letters to your patent attorney?

Answer. I have not carried it in my mind, but I think that date can undoubtedly be fixed by some memoranda of the event, and at all events would be somewhat closely indicated by the date of the affidavit, to which photolithographic copies of these letters were attached, in the record of one of my patents in the Patent Office, as the reason for calling for these letters was the execution of that affidavit by Mr. Baker.

[fol. 674] 290. Cross-question. As I understand it, however, you are not sure that you saw the originals of these letters at that time?

Answer. At the time that they were produced I can not remember positively. I simply have a recollection that I was present and saw the letters.

291. Cross-question. After Mr. Baker produced these letters for the purpose of making this affidavit, you did not personally see the originals of these letters again, until shortly before you testified in the Atlantic Communication Co. case, which was in 1915, did you?

Answer. Yes; I have a recollection that from time to time when I had occasion to go through the safe of the Stone Co., or my own safe, I came across these letters or had occasion to move them from one place to another in the safe.

292. Cross-question. Were these letters, when kept in the safe, inclosed in an envelope?

Answer. Yes; my recollection is that they were inclosed in an envelope indorsed by the office stenographer and bookkeeper, or in her handwriting. The letters were, as I remember it, in an envelope, and the photolithographic copies were in a flat package.

293. Cross-question. Can you say that from the time that Baker returned these letters to the company's files, and until shortly before you testified in the Atlantic Communication Co. case, in 1915, that you ever actually opened the envelopes and examined the originals of these letters, defendant's Exhibits Nos. 2 and 3?

Answer. I do not think I ever did actually examine the contents more than to glance through to see what it was, to make sure that the other document or paper I was looking for was not in that envelope.

294. Cross-question. For how late a period was Mr. Baker employed by the Stone Co., or as one of your assistants?

Answer. Mr. Baker's employment by the Stone Co. was, as I remember it now, not directly as one of my assistants. It was sporadic, and as I remember, only for brief periods, for special work, and I can not place it. I should say that he was not employed by the Stone Co. after 1903.

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Redirect examination.

By Mr. Scull:

295. Redirect question. During recess have you looked up any memoranda or data which you had, which would enable you to answer accurately some of the questions on cross-examination, as to when the defendant's Exhibits Nos. 2 and 3 were received by you from Mr. Baker, and as to the whereabouts of those letters after they were written?

Answer. Yes.

296. Redirect question. Will you produce any such data as you have been able to find, bearing on these subjects?

Answer. I produce the original of a letter from Mr. Joseph B. Baker to Mr. Alexander Porter Browne, dated June 3, 1902.

Mr. Seull: I offer the letter in evidence and ask that it be marked "Defendant's Exhibit 7."

(Marked "Defendant's Exhibit 7.")

[fol. 675] Answer (continuing). I also have here the envelope which contained the original of defendant's Exhibit 1, this being the envelope which I recognize as having contained this exhibit while it lay in the company's safe and in my safe. It is an official envelope of the Stone Telegraph & Telephone Co., and bears the indorsement "Baker's letter to Stone, July 22, 1899," in a handwriting which I believe I recognize as that of my patent counsel, Mr. Alexander P. Browne. This indorsement is in pencil.

Mr. Seull: The envelope referred to is offered in evidence as defendant's Exhibit 8.

(Marked "Defendant's Exhibit 8.")

Answer (continuing). I also have and produce here an envelope in very fragmentary condition, which is also I recognize an official envelope of the Stone Telegraph & Telephone Co., bearing an indorsement "Original letter, Mr. Stone to Mr. Browne, August 2, 1900." Under the word "original" is a ditto mark, followed by "Letters from Mr. Stone to Mr. Baker." This indorsement is in ink, and I recognize it to be in the handwriting of Miss Higgins, the stenographer and bookkeeper at the office of the Stone Telegraph & Telephone Co., 31 State Street, Boston

Mr. Seull: The envelope referred to is offered in evidence and is marked "Defendant's Exhibit 9."

(Marked "Defendant's Exhibit 9.")

Answer (continuing). I recognize this envelope, defendant's Exhibit 9, as the envelope that contained the originals of defendant's Exhibits Nos. 2 and 3, as they lay in the safe of the Stone Co., and afterwards, in my safe.

I have here an attested statement by Miss G. A. Higgins, executed January 4 ,1904, containing a copy of the original

of defendant's Exhibit 1. If my memory serves me correctly this attested statement was also preserved in the safe of the Stone Co. during its period of activity, and afterwards kept in my safe and finally handed over by me to my patent counsel, Mr. Alexander P. Browne, and placed in his safe.

Mr. Scull: The document referred to is offered in evidence by the defendant, and is marked "Defendant's Exhibit 10."

(Marked "Defendant's Exhibit 10.")

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297. Redirect question. With this document, defendant's Exhibit 10, before you, can you now state when the photolithographic copies of which the defendant's Exhibit 1 is one, was made from the original?

Answer. It appears to have been made on January 4, 1904, or thereabouts.

298. Redirect question. Were the originals of the letters defendant's Exhibits Nos. 2 and 3 written on the dates which appear thereon?

Answer. I have no doubt in my mind whatever that they were. I have no reason for supposing that they were written on any other date, and it is my custom to date letters on the date of the day that I write them.

299. Redirect question. Was there any reason which caused you to withhold the evidence of your 1899 invention from the various attorneys in the suits in which you testified, and about which you have been questioned on your cross-examination: and if so, what were such reasons?

[fol. 676] Answer. In the first place, I did not wish to give the date of my earliest proofs of priority in this invention to any parties until I was certain that a bona fide attempt would be made to prove the priority of my invention. So long as the Stone Co. or Stone Co.'s bondholders had possession of the patent 714756, and the subsidiary patents thereto, I was disinclined to disclose the state of my earliest proofs of priority to any one else, as I wished the priority of my invention to be established by the owners of the patent, who would be truly interested in making the defense of these patents complete. I wished the patents adjudicated if possible by a suit brought under them. I did not, however, withhold from any of the attorneys who consulted me

in regard to these patents, the fact that I considered myself the prior inventor, and that this patent No. 714756 was the first disclosure of the four-tune circuit invention published and supported by my proofs of early disclosure that would anticipate anyone else. When, however, the Atlantic Communication Co.'s counsel consulted me I was convinced that that company, in the defense of the suit brought against them by the Marconi Co. under its four-tune circuit patent, was going to make a perfectly bona fide Stone defense against this patent, and I forthwith wrote to my counsel of the firm of Browne & Woodworth asking them to send me the originals and photolithographic copies of the Baker letters, and submitted them to the counsel of the Atlantic Communication Co. By that time I was satisfied that the owners of the Stone Co.'s patents, including No. 714756, were not in a financial position to bring suits for infringements under that patent, and if they did bring such suits were not in a position to make the legal fight necessary to overcome the Marconi Co.'s claims. That about sums up the chief considerations that affected me in my course in that particular.

300. Redirect question. On cross-examination you were questioned in reference to your testimony in a suit in Philadelphia in which the Telefunken Co. was the defendant, and in which the patent in suit was the Fessenden patent No. 928371. At the time you testified in that suit, did you know of anything or did you have any reason to believe that the Telefunken Co. was or was not interested in establishing the date of your 1899 invention?

Answer. I had every reason to believe that the Telefunken Co. actually has a patent agreement with the Marconi Co. in this country comparable to their patent agreement in Europe, and I felt that I had reason for grave doubt as to the Telefunken Co.'s willingness to establish the validity of my patent No. 714756, as against the Marconi four-circuit tuning patent. In fact, I felt that the patent interest in this country of the Marconi Co. and of the Telefunken Co. were very closely allied, and everything that the Telefunken Co.'s counsel said to me at the time gave color to that belief on my part. He all but said that there was some such understanding between the companies.

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Mr. Scull. Attention is called to the fact that the answer is not intended to prove the truth of the statements made

therein, but rather to show the state of mind of the witness at that time.

301. Redirect question. What was the scope of the Fessenden patent No. 928371, involved in that suit, as far as it related to the tuning of the primary and secondary circuits? [fol. 677] Answer. Referring to a copy of Fessenden patent No. 928371, which I have before me, I will point out that in the first place it was restricted to the receiver circuits and in the second place that it was very distinctly limited to a structure almost if not identical with the structure of the Marconi receiver in the four-circuit patent, especially the British patent No. 7777, and covered only the variability of the different tuning elements in the two circuits at the receiver.

302. Redirect question. On cross-examination a statement was read from an affidavit made by you in a suit by the Marconi Co. against the Atlantic Communication Co. on the patents in suit herein, in which you referred to Lodge patent No. 609154 and in which you referred to the structure of Figure 4 as inefficient, etc. At the time you made that affidavit had you ever set up and tried or had any knowledge of anyone setting up and trying the structure of Figure 4 of that patent.

* * * * * * *

Answer. I do not think I every had any such tests made or ever knew of any such tests being made.

303. Redirect question. In your affidavit dated October 23, 1914, in the suit of Marconi against the De Forest Radio Telephone & Telegraph Co., and others, from which a long quotation beginning with "The opinions of Judges Parker and Veeder," etc., were quoted to you on this cross-examination, did you in that affidavit just prior to that quotation use the following language:

"If the two patents in suit had not been adjudicated, the interpretation to be placed upon the claims involved in this suit, would be a moot question to be determined by careful consideration of the prior art, the patents themselves, and their records in the Patent Office. But unfortunately both the Lodge and the Marconi patent in suit have been adjudicated in this country in these suits heretofore mentioned, tried before his Honor, Judge Veeder, and the corresponding patents in England, to the same inventors, have been adjudicated in a suit hereinbefore mentioned before Mr. Justice Parker. Both Justice Parker and Judge Vee-

der have given extensive opinions which leave little doubt as to the scope and significance or interpretation to be placed upon the patents to Lodge and Marconi, in suit."

Answer. I made that statement.

304. Redirect question. Also in this cross-examination, when the long quotation which I have referred to in the preceding question was placed upon the record, at a point which was omitted, about the middle of the quotation, did you make the following statement: after quoting claim 2 of the Marconi patent in suit:

"Without the benefit of the opinions of Mr. Justice Parker and Judge Veeder, the interpretation of this, as well as other of the claims of the patent, in the light of the prior art, the patent specification itself, and the explicit admissions of defendant in the record of this patent, would be extremely difficult since in terms, such a claim would be almost, if not quite the equivalent of a claim to the art."

Answer. I did.

305. Redirect question. On cross-examination you were asked whether you made this statement in answer to ques- [fol. 678] tion 16 in your deposition in the suit of the National Electric Signaling Co. against the Telefunken Wireless Co. on Fessenden patent No. 928,371:

"The first very clear and complete exhibition of the use of a continuously variable tuning condenser in shunt to the primary of a transformer in a wireless telegraph receiver, so far as I am aware, is contained in the specifications and drawings of the English patent to Marconi No. 7777 of 1900."

Please state whether that was in answer to the following question:

"Question 16. Prior to the patent in suit, and of the application therefore, was it new or old to use, in the primary and secondary circuits, or either, of a receiver system, a condenser shunted in either or both the primary or secondary circuits? Cite any instances, if you can, of any such published prior knowledge or use, either by a patent or a published book?"

Answer. It was.

306. Redirect question. Question 5 in this suit calls for a statement of the principles involved in radio telegraphy "as a practically applied art, down to and including Marconi's British patent No. 7777 of April 26, 1900." Was

your own invention at that time, April 26, 1900, a practically applied art?

Answer. No.

307. Redirect question. In that same suit you said in answer to question 107 as follows:

"All the best modern systems of modern telegraphy effect the tuning of a receiver to wave frequency by various methods, by involving electrical tuning produced by combinations of inductances of coils and capacities of condensers involving various arrangement of circuits."

Did you or not intend to include the Stone system as one of the best modern systems here referred to?

Answer. I did.

308. Redirect question. When you testified in the Atlantic Communication Co. case in Brooklyn, the record shows that you produced a document entitled "Stone Wireless Telegraph Syndicate agreement and declaration of trust," dated December 31, 1900. Have you that document?

Answer. No.

309. Redirect question. Do you know of its whereabouts?

Answer. It is in evidence in that case, presumed to be in the possession of the court.

Recross-examination.

By Mr. Betts:

310. Recross-question. Is it not your understanding that the same interests which controlled the Telefunken Wireless Telegraph Co. also controlled the Atlantic Communication Co.?

Answer. No. My impression is that it is not the same interests, but this is a mere impression. I do not know who controls the Atlantic Communication Co., and I never knew where the control lay in the old American Telefunken Co. I understood that it was partly owned by the German Telefunken Co. and partly owned by two brothers, Philadelphia merchants, but what the proportion of shares of these three interests was I never knew. At all events, I knew that the [fol. 679] two Americans seemed to have a good deal to say about the management of the affairs of that company.

311. Recross-question. You do understand, do you not, that the German Telefunken Co. is financially interested in the Atlantic Communication Co.?

Answer. I do not that for a fact, but I assume that the German Telefunken Co. has an interest in the Atlantic Communication Co.

312. Recross-question. Both the Telefunken Wireless Co. of America and the Atlantic Communication Co. marketed and used exclusively so-called Telefunken apparatus, so far as you know?

Answer. I am sure that most of their apparatus was German Telefunken apparatus, but I know that a certain amount of apparatus or at least I am quite certain that a certain amount of their apparatus was constructed here. Just what amount, or what parts, I do not know. I merely have it from hearsay that certain parts were manufactured here.

313. Recross-question. You do not wish to be understood as testifying that there was a matter of fact an agreement between the Marconi Co. and the Telefunken Co. of America?

Answer. No; I do not know anything about it. I had every reason to suspect that there was at one time, at the time of the Philadelphia suit under the Fessenden patents.

314. Recross-question. Where is that letter dated June 23, 1899, which you wrote to Baker, and which is referred to in defendant's Exhibit No. 7?

Answer. I do not know. I believe that letter had no particular reference to the invention of my United States patent No. 714756.

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315. Recross-question. Can you produce the letter dated June 23, 1899, referred to in defendant's Exhibit No. 7?

Answer. I do not know whether I can or not. I do not know where the letter is at present. It may be in Mr. Browne's safe or the safe of the firm of Browne & Woodworth in Boston.

316. Recross-question. Where is the letter dated August 2, 1900, from you to Mr. Browne, referred to on the envelope which is marked "Defendant's Exhibit No. 9?"

Answer. I do not remember where that letter is, but I believe that I have recently seen a photolithographic copy of that letter or the letter itself, and that I found it to be a letter describing to Mr. Browne my system of automatically relaying wireless telegraph messages, the letter being directed to Mr. Browne at his home in Nantucket. That is

the only recollection I have of it. I think I can secure the letter or a photolithographic copy of it, by writing to Messrs. Browne & Woodworth for it; or I may even have the letter or a photolithographic copy of it amongst some papers that were sent to me by Browne & Woodworth for use in the Marconi versus Atlantic Communication Co. suit.

Redirect examination.

By Mr. Scull:

317. Redirect question. When did you give this testimony in Philadelphia on the Fessenden patent No. 928371?

Answer. In September, 1911.

[fol. 680] (It is stipulated and agreed that the exhibits produced in connection with the depositions of the witnesses Baker and Stone may be retained in the possession of respective counsel producing them until the trial of this cause.)

Walter C. Dean, called as a witness on behalf of the defendants, being sworn, testified as follows:

Direct examination.

By Mr. Knight:

1. Question. Will you state your occupation, Mr. Dean?

Answer. I am electrical expert aide at the Bureau of Construction and Repair, Navy Department, Washington.

2. Question. State briefly your technical experience?

Answer. I was a graduate in the department of electrical engineering at the Massachusetts Institute of Technology, class of 1900, and received the degrees of bachelor of science and electrical engineer.

3. Question. And since then what have you done, if anything, in connection with wireless telegraphy and similar studies?

Answer. Subsequently I was employed by the Navy Department, beginning in the fall of 1900, as a laboratorian. In 1901 I was appointed under the civil service as electrical draughtsman at the Norfolk Navy Yard. In 1903 I became interested in wireless telegraphy and assisted in the installations of land stations in the fifth naval district. I also had

charge or technical supervision of ship installations at that navy yard until about 1907, when my time was more fully occupied with other electrical matters.

4. Question. State what your course at the Massachusetts Institute of Technology covered, under what professors you studied, and what the courses were.

Answer. Those courses which related to wireless telegraphy began with a course in physics under Prof. Charles R. Cross, head of the electrical department, in which we considered the early development, beginning with the Hertz experiments and the Lodge experiments. Paralleling this course, Prof. Harry Clifford gave us a course on theoretical electricity.

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Following the completion of the course in theoretical electricity at the end of the first semester of the senior year, January, 1900, we listened to a course on high frequency currents and their applications by Prof. John Stone Stone, which consisted of two lectures, in January, 1900.

5. Question. Please recount, referring to such notes as you may have, what those lectures of Professor Stone were on that subject.

Answer (referring to memoranda). I have nine pages of my original notes in my own handwriting which I took dur- [fol. 681] ing the course of lectures by Professor Stone. He first covered the analogy between electrical and mechanical vibrations, giving mathematical expressions, on the one hand, involving mass and elasticity, and in the other, namely, electrical conditions, the quantities of induction and capacity. He showed the mathematical expressions for a mechanical horizontal pendulum, showing the condition for free vibrations, three conditions, one of which was when friction squared equals four times the mass divided by the elasticity gave a harmonic vibration. He told us that the vibrations died away, due to damping, expressed by the logarithmic decrement.

He next considered oscillatory electrical circuits with variable induction and variable capacity, in which likewise he showed the condition for free or natural vibrations, and gave an equation for the current in such a circuit, when there was no electrical friction or resistance. He gave an expression for the frequency, in terms of capacity and inductance.